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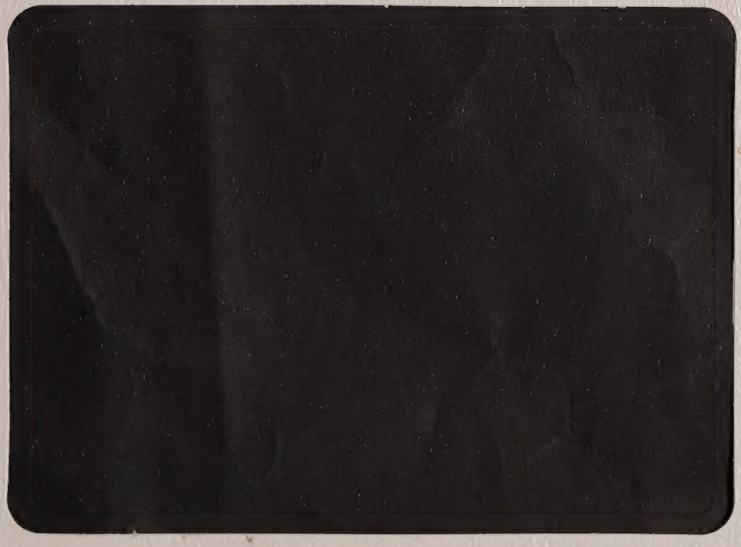

Instruction Manual

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Type 1316 Oscillator

Form 1316-0100-E

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Concord, Massachusetts, U.S.A. 01742
April, 1984

Specifications

Frequency: 10 Hz to 100 kHz in 4 decade ranges. Controlled by one 11-position and one 10-position switch for the most-significant digits and a continuously adjustable dial with detented zero-position for the third digit; in-line readout with decimal point and frequency units.

Accuracy: ±1% of setting.* *Drift* (typical at 1 kHz), warmup 0.1%, short-term (10 min) 0.001%, long-term (12 h) 0.005%. *Resettability*, within 0.005%.

Power Output: *Controlled* by 5-position switch and uncalibrated vernier. *Monitored* by meter with ±3% accuracy. *Available* at rear BNC connector.

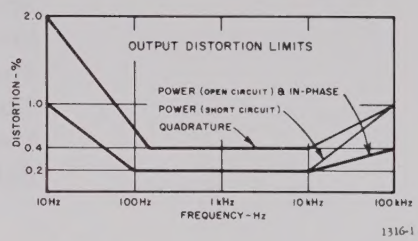
*With continuously adjustable dial set at zero detent position.

Output Range

	1.5 V	5 V	15 V	50 V	150 V
Open circuit, rms	≥ 1.25 V	≥ 4 V	≥ 12.5 V	≥ 40 V	≥ 125 V
Distortion	< 0.2% from 100 Hz to 10 kHz				
Hum	0.003% of max output				
Response	output constant within ±2% from 10 Hz to 50 kHz, ±5% for frequencies >50 kHz				
Short Circuit	5 A	1.6 A	0.5 A	0.16 A	0.05 A
Distortion	< 0.2% from 100 Hz to 10 kHz				
Impedance	0.25 Ω	2.5 Ω	25 Ω	250 Ω	2.5 kΩ
Power	1.6 W nominal into matched load				

Reference Outputs: Quadrature output **lags** in-phase output by 90°. Each available at rear BNC connectors.

	In-Phase	Quadrature
Output, open-circuit	1.25 ±0.25 V rms	
Distortion, 100 Hz to 10 kHz	< 0.2%	< 0.4%
Response, 10 Hz to 10 kHz	±2%	
10 kHz to 100 kHz	±4%	
Minimum Load	47 kΩ	



1316-1

Synchronization: *Input*, frequency can be locked to external signal; lock range, ±1%/V rms input up to 10 V; frequency controls function as phase adjustment. *Output*, ≥0.3 V rms behind 27 kΩ; useful to sync oscilloscope or to drive a counter or another oscillator. Single rear BNC connector serves as both input and output terminal.

Power: 100 to 125 and 200 to 250 V, 50 to 60 Hz, 36 W.

Mechanical: Bench or rack mount. *Dimensions* (w × h × d): Bench, 19.75 × 5 × 13.06 in. (502 × 127 × 332 mm); rack, 19 × 3.47 × 11.44 in. (483 × 88 × 291 mm). *Weight:* Bench, 26 lb (12 kg) net, 32 lb (14 kg) shipping; rack, 21 lb (10 kg) net, 27 lb (12 kg) shipping.

Catalog Number	Description
	1316 Oscillator
1316-9700	Bench Model
1316-9701	Rack Model

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Introduction—Section 1

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1.1 PURPOSE.

The Type 1316 Oscillator is a high-performance instrument with an output of 10 Hz to 100 kHz. It was specifically designed for use with the Type 1238 Detector and the Type 1616 Precision Capacitance Bridge, and is also an excellent general purpose instrument.

1.2 DESCRIPTION.

The 1316 Oscillator is a decade-conductance-tuned, Wien-bridge oscillator containing a low-distortion power amplifier that is transformer coupled to provide isolation from the load. Output power and frequency are selected by front-panel controls; all external connections are made to the rear panel for clutter-free operation.

A provision to introduce or extract a synchronizing signal is included in the oscillator circuit. The extracted signal is independent of the output setting and can be used to operate a counter or to synchronize an oscilloscope.

Other features are: unambiguous in-line readout, decade-frequency selection with positioned decimal point and units, and two reference outputs (IN-PHASE and QUADRATURE). The reference outputs are for use with the Type 1238 phase-sensitive Detector.

1.3 CONTROLS, CONNECTORS, AND INDICATORS.

The front- and rear-panel controls, connectors and indicator are shown in Figures 1-1 and 1-2 respectively. Refer to Tables 1-1 and 1-2 for a functional and physical description.

1.4 SYSTEMS.

The 1316 oscillator is used as a component in the 1621 Precision Capacitance Measurement System (Figure 1-3).

1.5 ACCESSORIES SUPPLIED.

A 3-wire, 7-ft power cord (P/N 4200-9625) is supplied with the instrument.

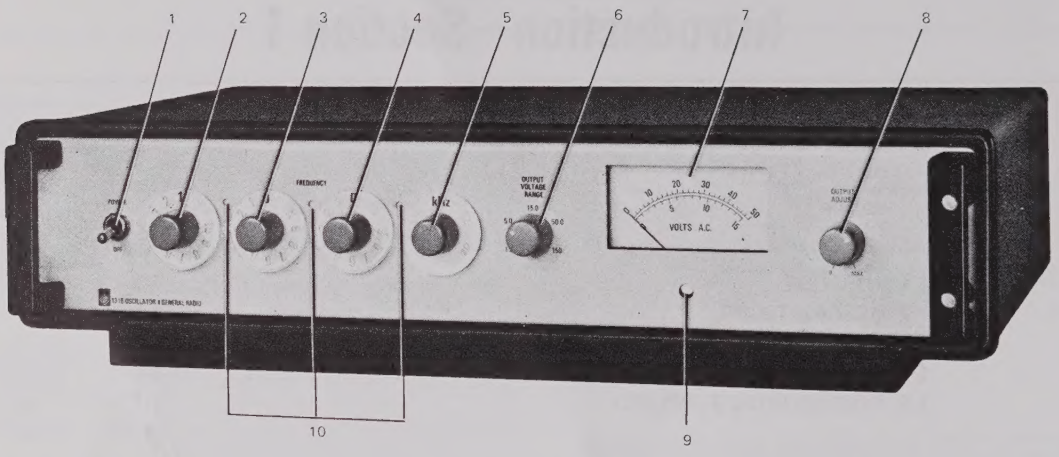

Figure 1-1. Front-panel controls, connectors and indicators.

Table 1-1

FRONT PANEL CONTROLS AND INDICATOR

Figure 1-1 Ref. No.	Name	Description	Function
1	POWER switch	2-position toggle switch, down position: OFF.	Turns instrument on or off.
2	FREQUENCY selector	10-position rotary switch, dial-marked 1 to 10.	Selects and indicates 1st digit of frequency.
3	FREQUENCY selector	11-position rotary switch, dial marked 0 to 9 and X (X indicates 10 ***or 0***).	Selects and indicates 2nd digit of frequency.
4	FREQUENCY selector	Stepless potentiometer, dial marked 0 to 9 with detent at 0.	Selects and indicates 3rd digit of frequency.
5	FREQUENCY range switch	4-position switch, dial marked Hz, Hz, kHz, and kHz.	Selects frequency range, indicates units, and controls illuminated decimal point.
6	OUTPUT VOLTAGE RANGE switch	5-position rotary switch, panel-marked 1.5, 5.0, 15.0, 50.0, and 150.	Selects output-voltage range and indicates full-scale meter range (item 7). Simultaneously switches the output impedance from 0.25 Ω to 2.5 kΩ in decade steps.
7	Voltmeter	Ac meter with 0-15 and 0-50-V scales.	Indicates output terminal voltage, in ranges selected by item 6.
8	OUTPUT ADJUST control	Stepless, rotary potentiometer with limits labeled 0 and MAX.	Controls output level in the range selected by item 6.
9	————	Zero-adjust screw.	Mechanically adjusts output-voltage meter for mechanical zero.
10	————	Front-panel, white indicator lights.	Indicates position of decimal point, controlled by the FREQUENCY range switch (item 5).

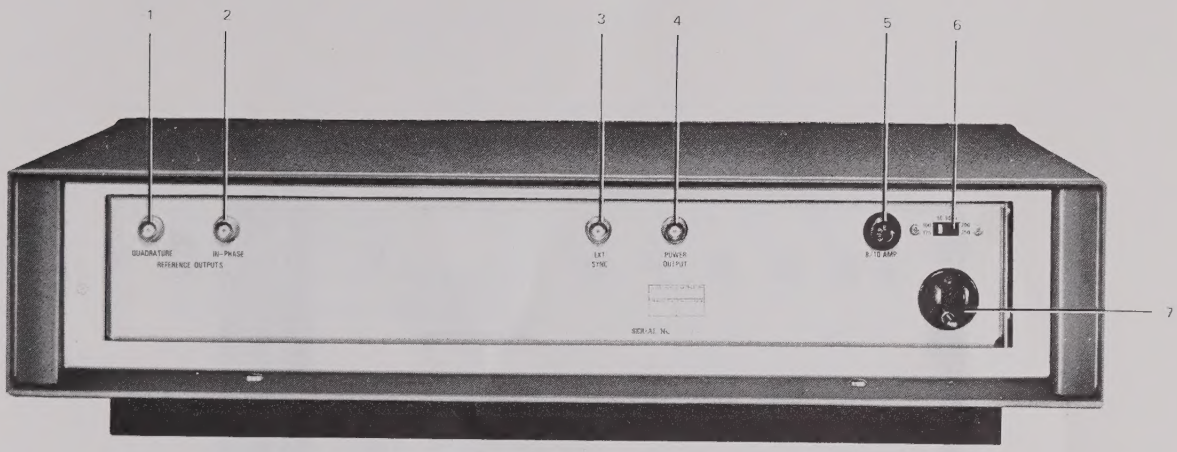

Figure 1-2. Rear-panel control and connectors.

Table 1-2

REAR-PANEL CONTROLS AND CONNECTORS

Figure 1-2 Ref. No.	Name	Description	Function
1	QUADRATURE REFERENCE OUTPUT	BNC jack	Provides a reference output that lags the "in-phase" reference by 90° at 1.25 V o.c.
2	IN-PHASE REFERENCE OUTPUT	BNC jack	Provides a reference output, in-phase with power output, at 1.25 V o.c.
3	EXT SYNC connector	BNC jack	For synchronizing output frequency to an external source (lock range is ±1%/Vrms, up to 10 V) or constant-amplitude signal source (0.3 V behind 27 kΩ).
4	POWER OUTPUT connector	BNC jack	Main output, 1.6 W nominal may be 125 V o.c. or 5 A s.c.
5	Fuse	Bussman MDL 8/10 A, slo-blo	Protection against damage from a short circuit for 110- or 220-V operation.
6	50-60 Hz 100 V-125 V 200 V-250 V	Two-position slide switch	Switches line power connection for either 110-V or 220-V operation.
7	————	Three-pin power plug	Accepts 3-wire line cord to power instrument.

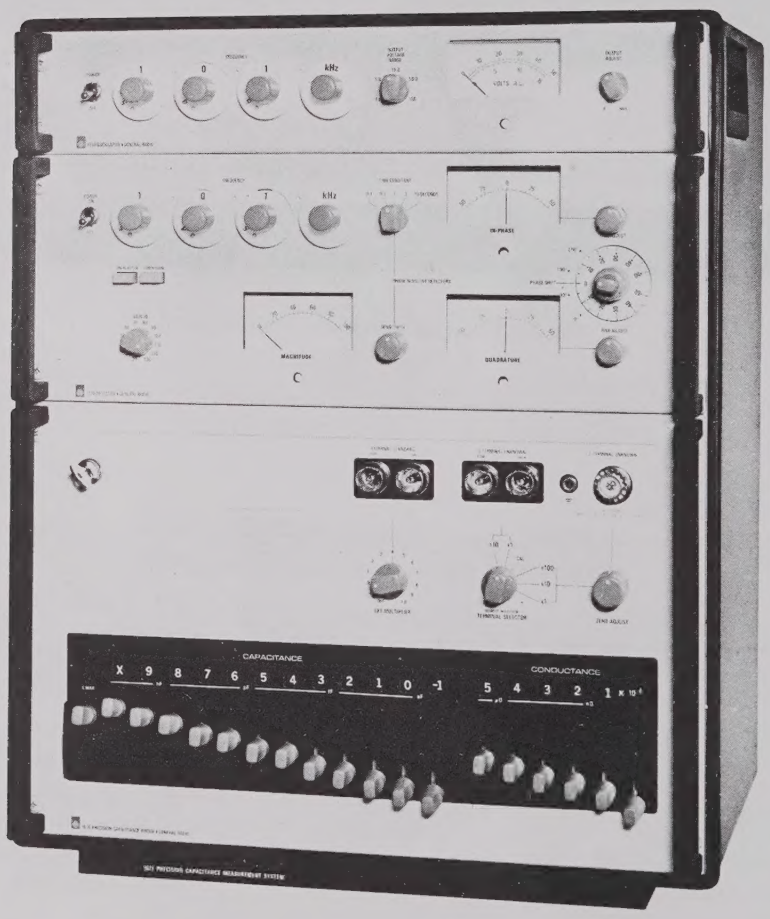

Figure 1-3. Type 1621 Precision Capacitance-Measurement System.

Installation—Section 2

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2.3 POWER-LINE CONNECTION 2-1
2.4 BENCH MODELS 2-1
2.5 RACK MODELS 2-2
2.6 LINE-VOLTAGE REGULATION 2-4
2.7 EXTERNAL CONNECTIONS 2-4

2.1 GENERAL.

The Type 1316 Oscillator is available for either bench use or installation in an EIA Standard RS-310,19-in. relay rack with universal hole spacing. Appropriate cabinet and hardware sets are available for conversion of a bench model for rack installation or vice versa.

2.2 DIMENSIONS.

Outline drawings showing overall dimensions of the oscillator in bench and rack models are shown in Figure 2-1.

2.3 POWER-LINE CONNECTION.

Power requirement is 36 W at 100 to 125 or 200 to 250 V, 50 to 60 Hz. Make connections as follows:

a. Set the line-voltage switch on the rear panel to correspond with the available power-line voltage. Use a small screwdriver to slide the switch.

b. Connect the external power line to the power plug, using the power cord supplied or an equivalent, 3-conductor cord.

A single 8/10-A fuse protects both the low- and high-voltage circuits.

2.4 BENCH MODELS.

2.4.1 General.

Each bench model comes completely assembled in a metal cabinet intended for use on a table or laboratory bench. The instrument is mounted on tracks that permit easy removal for inspection or repair.

2.4.2 Cabinet Removal.

a. Set the instrument in the horizontal position, free of unnecessary cables.

b. Remove the four dress-panel screws (A), accessible through holes in the handles.

c. Carefully pull the instrument out of the cabinet.

2.4.3 Conversion for Rack Mounting.

To convert a bench instrument for rack mounting, exchange the cabinet and install appropriate hardware, as follows:

a. Obtain a Rackable Cabinet Assembly P/N 4174-3240 (Table 2-1) from General Radio Company.

b. Obtain, optionally, Bracket Set P/N 4174-2007 (Table 2-2). This is especially recommended for a heavy instrument, which needs support from the rear rail of the rack.

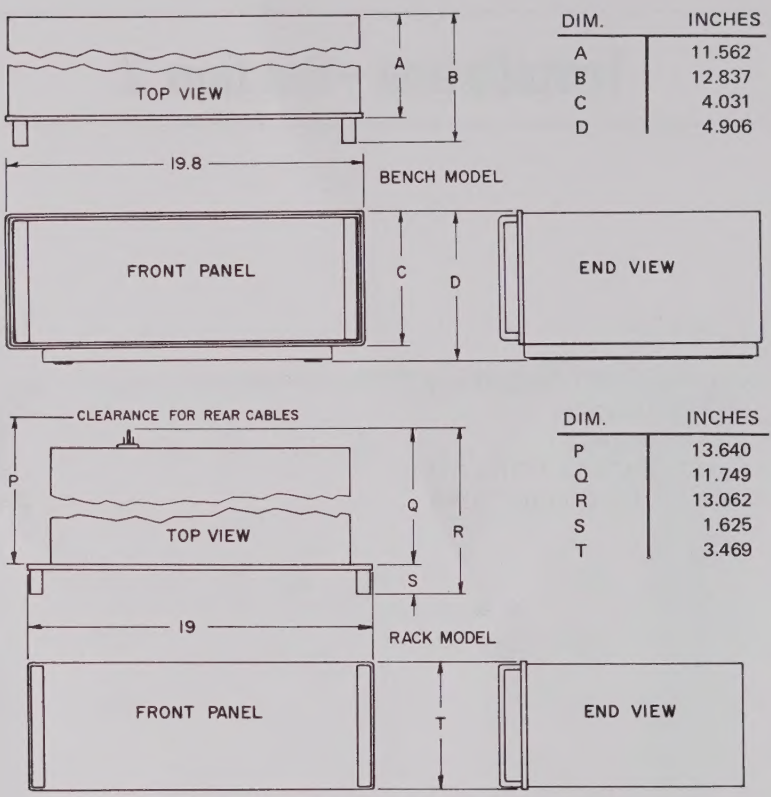

Figure 2-1. Dimensions of the 1316 bench and rack-model instruments.

c. Remove the cabinet, as in paragraph 2.4.2.

d. Remove the rear cover from the bench cabinet, with screws (B Figure 2-2) , for later installation on the rack cabinet.

e. Proceed with the rack installation; skip to paragraph 2.5.2, step b.

2.5 RACK MODELS.

2.5.1 General.

Each rack model comes completely assembled in a suitable metal cabinet, which is designed to stay semipermanently in a rack. The instrument can be drawn forward on extending tracks for access with support, or (with a lift) withdrawn completely. The cabinet and hardware listed in Tables 2-1 and 2-2 are all included with a rack-model instrument.

2.5.2 Installation. Figure 2-3

Directions follow for mounting the cabinet in a rack and installing the instrument on its tracks:

a. Remove 4 dress-panel screws (A) and slide the instrument out of the cabinet until the tracks are fully extended. Continue pulling the instrument forward until motion along the tracks is stopped. At this juncture, tilt the front of the instrument up slightly and continue withdrawal, past the stops, until it is free.

b. Insert the rack cabinet wherever desired in the rack — be sure it's level — and fasten it with 4 screws (C) to the front rails.

c. If the rack contains a rear support rail, use brackets (D) to support the cabinet with the rear rails; open-slotted screw holes allow positioning.

d. Use the set of slots in the sides of the cabinet that allow alignment of the open-slotted holes in the brackets with threaded holes in the rail. The long flange should extend to the rear.

e. Insert screws (E) from inside the cabinet, through the slotted holes and drive them into the holes in the long flange of the bracket. Each side takes 2.

Table 2-1

RACKABLE CABINET ASSEMBLY (P/N 4174-3240)

Quantity	Description	
1	Hardware set, including:	4174-2004
	2 Screws, 0464-32, 1/4-in, thread forming ("B" for rear cover).	——
	4 Screws, 0.190-32, 9/16 in, dress ("A" for front panel).	——
	4 Sets of 10-32 nuts and washers (for screws "A", if needed).	——

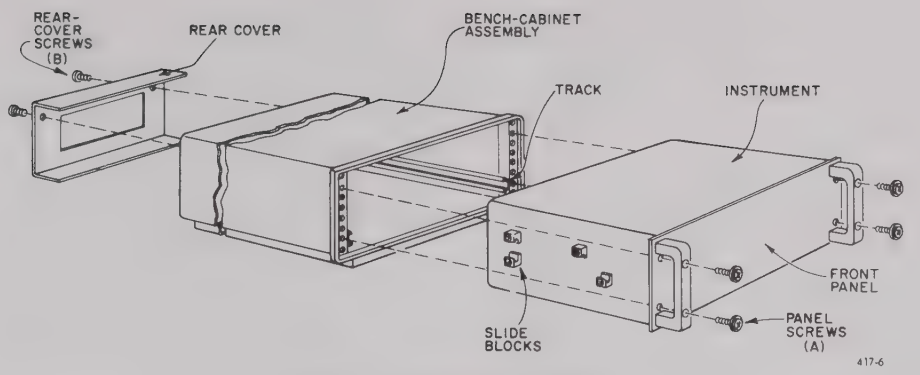

Figure 2-2. Bench-cabinet installation.

NOTE

Start the screws in the appropriate holes off the rack, to make the threading easier.

f. Pass screws (B) through brackets and screw 2 into each rear rail. (Details may be varied to suit particular situations.)

g. To install the instrument, first set its rear edge in the cabinet front opening. Slide the instrument back, making sure that the rear and the upper front slide blocks engage the tracks. (Stops prevent further insertion.)

h. Pull the instrument forward ***with*** the tracks, keeping a hand on each side (fingers underneath). Slide the instrument back about ½ in. along both tracks, past the stops, by pressing down on the tracks (with thumbs) while tilting the front of the instrument up slightly.

i. Push the instrument back into the rack, checking for smooth operation of the tracks and slide blocks.

NOTE

The instrument is now readily accessible for behind-the-panel adjustments. It slides in and out freely on extending tracks.

Table 2-2

BRACKET SET FOR RACK MODEL (P/N 4174-2007)

Ref.	*Quantity*	*Description*
D	2	L brackets with open-slotted holes.
E	4	Screws, 8-32, 3/16 in., thread forming.
C, B	8	Screws, 10-32, 1/2-in., thread forming.

2.5.3 Conversion for Bench Use.

To convert a rack-mounting instrument for bench use, exchange the cabinet, as follows:

a. Obtain a Bench Cabinet assembly P/N 4172-4015 (Table 2-3) from General Radio Company.

b. Remove the instrument from the rack cabinet, using the procedure in step a, para. 2.5.2.

c. Stand the instrument face down, to rest on its handles, and slip the bench cabinet over it. Carefully return it to a horizontal position.

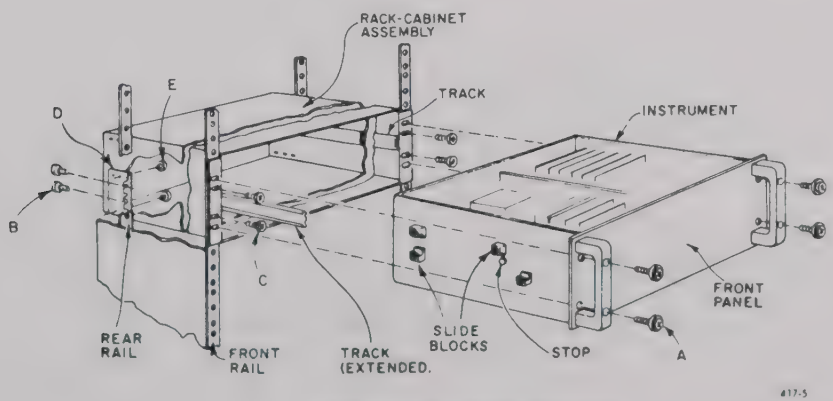

Figure 2-3. Rack-cabinet installation.

d. Fasten the instrument to the cabinet using dress-panel screws (A, Figure 2-2).

e. Transfer the rear cover, with screws (B), from rack cabinet to bench cabinet.

2.6 LINE-VOLTAGE REGULATION.

The accuracy of measurements accomplished with precision electronic test equipment operated from ac line sources can often be seriously degraded by fluctuations in primary input power. Line-voltage variations of ±15% are commonly encountered, even in laboratory environments. Although most modern electronic instruments incorporate some degree of regulation, possible power-source problems should be considered for every instrumentation setup. The use of line-voltage regulators between power lines and the test equipment is recommended as the only sure way to rule out the effects on measurement data of variations in line voltage.

2.7 EXTERNAL CONNECTIONS.

2.7.1 General.

All external connections to the Type 1316 Oscillator are made to rear-panel BNC connectors. This feature facilitates the use of the 1316 in the Type 1621 Precision-Capacitance-Measurement System (Figure 1-3).

2.7.2 POWER OUTPUT Connector.

The main output of the oscillator is available at the rear-panel POWER OUTPUT jack. Output-voltage range and amplitude are controlled by the front-panel OUTPUT VOLTAGE RANGE and OUTPUT ADJUST controls respectively.

2.7.3 EXT SYNC Connector.

A single rear-panel BNC connector serves the dual purpose of an input or output jack. As an input, the oscillator frequency can be locked to an external signal. The lock range is ±1%/V rms input, up to 10 V, and the front-panel frequency controls function as the phase adjustment. As an output, 0.3 V rms behind 27 kΩ is available to lock the frequency of another instrument to that of the oscillator.

2.7.4 REFERENCE OUTPUT Connectors.

General. The REFERENCE OUTPUT connectors were designed into the Oscillator primarily to provide low-level fixed-amplitude reference signals for the Type 1238 Detector. However, they can be used for any application requiring a pair of 1-V reference signals with a phase difference of 90°.

IN-PHASE. The IN-PHASE output jack provides a reference voltage that is in phase with the main POWER OUTPUT of the 1316 Oscillator. This voltage (open circuit) is 1.25 ±0.2 V rms. Distortion is less than 0.2% from 100 Hz to 10 kHz and the voltage response is typically ±2% from 10 Hz to 10 kHz, and ±4% from 10 kHz to 100 kHz. ***The minimum load impedance should be 47 kΩ.*** A smaller impedance will reduce the output voltage and possibly cause distortion.

Table 2-3

BENCH CABINET ASSEMBLY COMPLETE (4172-4015)

Quantity	Description	Part No.
1	Bench Cabinet Assembly, including:	4172-2042
	1 Cabinet	
	1 Gasket	
	1 Base with hardware (includes hinge and toggles)	
	Factory assembled with:	
2	Tracks	
2	Brackets, rear, (and screws)	
	Supplied with:	
2	Screws, 0.164-32, 1/4 in., thread forming ("B" for rear cover)	——
4	Screws, 10-32, 9/16 in., dress ("A" for front panel)	——

QUADRATURE. The QUADRATURE output jack provides a reference voltage that leads the IN-PHASE and POWER OUTPUT voltages by 90°. This voltage (open circuit) is 1.25 ±0.2 V rms. Distortion is less than 0.4% from 100 Hz to 10 kHz and the voltage response is typically ±4% from 10 kHz to 100 kHz. ***The minimum load impedance should be 47 kΩ.***

NOTE

The instrument is fitted with a new-design power-connector that is in conformance with the International Electrotechnical Commission publication 320. The 3 flat contacts are surrounded by a cylindrical plastic shroud that eliminates the possibility of electrical shock whenever the power cord is being unplugged from the instrument. In addition, the center ground pin is longer, which means that it mates first and disconnects last, ensuring greater user protection from electric shock.

The panel connector is a standard 3-pin grounding-type, the design of which has been accepted world wide for electronic instrumentation, and is rated for 250 V at 6A. It also meets requirements of Underwriter's Laboratories in the U.S. and the Canadian Standards Association. The receptacle accepts power cords fitted with the Belden type SPH-386 connector.

Operation – Section 3

3.1 GENERAL 3-1
3.2 OPERATIONAL CHECKS 3-1
3.3 NORMAL OPERATION 3-2
3.4 APPLICATIONS 3-2

3.1 GENERAL.

This section contains operational checks, operating instructions, and a basic description of some applications for which the 1316 Oscillator can be used.

3.1.1 Equipment Turn-on.

To prepare the instrument for use, perform the following steps:

a. Set the rear-panel line-voltage selector switch to the line-voltage used (100-125 V or 200-250 V, 50-60 Hz), and connect the instrument to the power line, using the power cable supplied.

b. Set the power switch to POWER. One of the decimal-point lamps should glow. Its position will depend on the FREQUENCY range-switch setting (Refer to Table 3-1).

3.1.2 Meter Zeroing.

The output voltage meter has been zeroed at the factory. If it becomes necessary to re-zero the meter, proceed as follows:

a. Check to see that the POWER switch is set to OFF. If the instrument has been operating, allow sufficient time for the meter indicator to stabilize near zero.

b. Adjust the meter zero-adjust screw for a zero indication. Gently tap the meter face occasionally during adjustment.

c. Set the oscillator controls for any output within the range of the instrument.

d. Turn on the oscillator. Note that an output is indicated and then turn off the oscillator.

e. Check to see that the meter indicator stabilizes on zero.

3.1.3 Stray Capacitance.

Stray capacitance of most shielded leads or coaxial cables is about 30 pF per foot, which, at 100 kHz, amounts to a shunt impedance of about 55 kΩ. Therefore, the cable length should be kept to a minimum when a high-impedance load is to be driven at high frequencies.

3.2 OPERATIONAL CHECKS.

3.2.1 General.

These procedures can be used for incoming inspection, operator familiarization, or as a periodic quick-check on instrument operation. Table 5-1 includes recommended test equipment for these checks. Refer to para. 5.8 if unable to obtain the performance called for.

Table 3-1

DECIMAL POINT POSITION

Position of A-S5 (from fully counterclockwise)	POSITION OF DECIMAL POINT*
1 (Hz)	XX.X
2 (Hz)	XXX.
3 (kHz)	X.XX
4 (kHz)	XX.X

*X = a frequency dial

3.2.2 Output Frequency.

The frequency of the oscillator output signal should correspond with the setting of the FREQUENCY selectors. For a quick-check of output frequency proceed as follows:

a. Set the 1192 counter controls to measure frequency and connect it to the oscillator POWER OUTPUT jack.

b. Turn the oscillator on and set the frequency selectors for any frequency between 10 Hz and 100 kHz.

c. Observe the counter visual register. It should display the same frequency set by the frequency selectors ±1 count.

3.2.3 Output Voltage.

The Oscillator is equipped with an ac voltmeter for monitoring the output voltage. For an operational check of the output voltage, simply turn the instrument on, set the frequency and voltage controls for some value within the range of the instrument, and observe the front-panel meter. This meter will indicate the voltage at the output jack within ±3%.

3.3 NORMAL OPERATION.

To use the instrument as a source:

a. Turn on the oscillator and allow approximately 1 minute for it to reach normal operating temperature. For optimum frequency and amplitude stability allow 30-minutes warmup.

b. Set the FREQUENCY range switch to the desired frequency range. Notice that this control positions the decimal point.

c. Set the FREQUENCY selectors to the desired frequency.

d. Set the OUTPUT VOLTAGE RANGE switch to the range that will provide the desired output voltage.

e. Adjust the OUTPUT ADJUST control to obtain the desired output voltage reading on the output voltage meter.

To use the instrument synchronized to an external source.

a. Perform steps a-e above.

b. Connect the external signal to the EXT SYNC jack (Figure 1-2). The lock range of the oscillator is ±1%/V rms sync input up to 10 V. For example, if a 1-kHz, 1-V sync signal is used, the oscillator output frequency will lock to the external signal within the range 990-1010 Hz. If the sync-signal voltage is doubled the lock range also doubles (980-1020 Hz).

The oscillator will remain synchronized so long as it is operated within the lock range.

3.4 APPLICATIONS.

3.4.1 General.

One of the most important features of the Type 1316 Oscillator is that it provides an easy-to-read, unambiguous, repeatable, in-line readout of its frequency. This will be of value in production testing and calibrating where many accurate and repeatable frequencies must be selected quickly.

Some typical applications are presented in the following paragraphs.

3.4.2 Slaved Oscillators.

Because the EXT SYNC jack is simultaneously an input and an output connector, two or more oscillators can be synchronized or slaved by connecting their EXT SYNC jacks together (Figure 3-1). Oscillators connected in this manner will operate at the same frequency, or multiple thereof, and can be made to differ in phase (180° ±75°) by adjustment of the frequency selectors within the lock range. The lock range is ±1%/V rms input up to 10 V.

Another obvious application is to lock one or more oscillators to a reference source that has greater accuracy and long-term stability. This is done by connecting the source to the EXT SYNC jack. If more than one oscillator is to be used, connection between instruments is shown in Figure 3-1. With the instrument(s) synchronized in this fashion accuracy and long-term stability will be identical with the reference; short-term stability will be the same as if the oscillator was free-running.

3.4.3 Amplitude-Modulated Oscillator.

Amplitude modulation. If the oscillator is operated outside of the lock range, the sync signal will beat with the oscillator frequency and produce an audio-frequency, amplitude-modulated output. The modulation will be approximately sinusoidal for modulation levels up to about 10%.

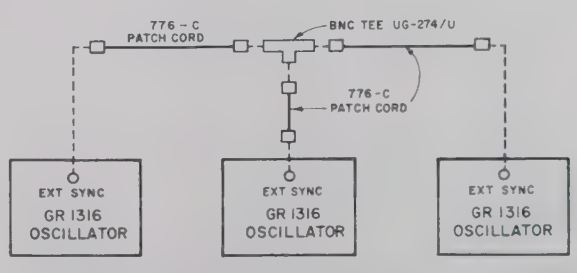

Figure 3-1. Method of connecting slaved oscillators.

This arrangement is not ideal, but it does provide amplitude-modulated signals in the audio range where normally they are not conveniently obtainable. Modulated outputs of this type can be used to measure the effects of incidental am on other measurements and to provide a modulated source to reduce meter-friction errors in ac measurements.

The figure shows one example of amplitude modulation:

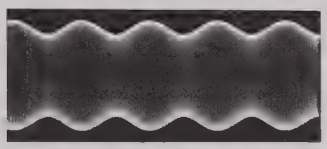

Figure 3-2. 10-kHz output of an oscillator modulated at 500 Hz by a 9.5-kHz signal applied to the EXT SYNC jack.

3.4.4 Output Sync.

Oscilloscope trigger. Since the sync output is independent of the output level, it can be used to trigger an oscilloscope in applications where the oscillator output is often varied, thereby eliminating frequent readjustment of the oscilloscope trigger circuits.

Counter trigger. A counter can be driven from the EXT SYNC jack when more precise adjustment of frequency is desired or when the front-panel output is not sufficient to trigger the counter.

3.4.5 Systems Use.

All external connections to the oscillator are made at the rear panel — a convenient feature for systems use. The 1316 is one of 3 integrated units in our Type 1621 Precision Capacitance Measurement System (Figure 1-3). It functions as the drive oscillator for the system and supplies the detector with 2 reference inputs. The high level, stability, and low-noise characteristics of this oscillator play a large role in producing the ultra-precise measurements and comparisons that the system is capable of providing.

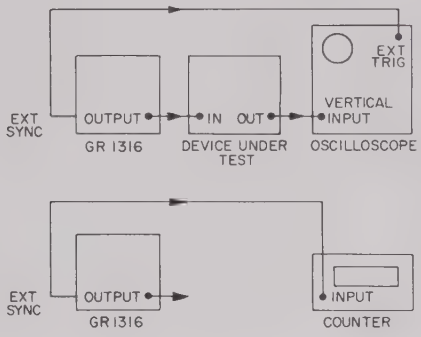

Figure 3-3. The oscillator used to trigger: a. an oscilloscope; b. a counter.

Theory–Section 4

4.1 GENERAL 4-1
4.2 WIEN-BRIDGE THEORY 4-2
4.3 CIRCUIT DESCRIPTION 4-3
4.4 SYNCHRONIZATION 4-5

4.1 GENERAL.

Figure 4-1 is a functional block diagram of the Type 1316 Oscillator. The 1316 is comprised of a conductance-tuned oscillator (a modification of the Wien bridge) followed by an output amplifier, an autotransformer, and a meter circuit.

The oscillator frequency is varied in four decade steps by effectively changing the capacitance (C) of the modified Wien bridge, and is varied in smaller, discrete steps by changing two conductance decades (G). The continuously adjustable decade varies the frequency by altering the voltage across conductance g, thereby, changing the effective conductance.

Wien-bridge theory is essential to comprehending how the 1316 circuitry functions. Therefore, para. 4.2 precedes a basic circuit description for this instrument.

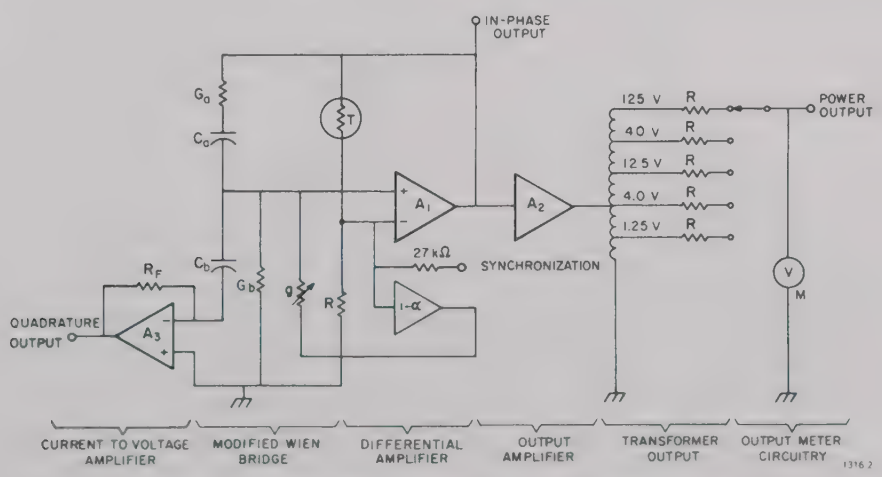

Figure 4-1. Functional block diagram of the type 1316 decade oscillator.

4.2 WIEN-BRIDGE THEORY.

4.2.1 General.

A Wien bridge (Figure 4-2) consists of two parts: a frequency-determining impedance divider, which provides positive feedback to sustain oscillation and an amplitude-determining resistive divider, which supplies negative feedback to stabilize amplitude. The following paragraphs explain how both of these work.

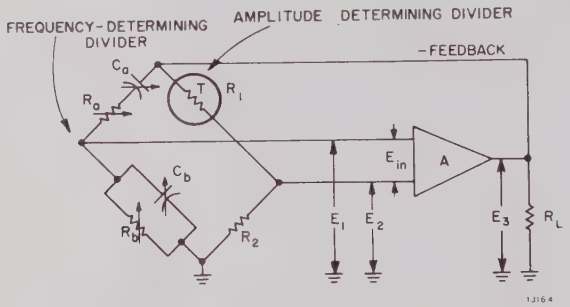

Figure 4-2. Schematic diagram of a typical Wien bridge.

4.2.2 Frequency. Figures 4-2 & 4-3.

The operating frequency, f_o, of a Wien-bridge oscillator depends on the values of the components in the impedance divider:

$$f_o = \frac{1}{2\pi\sqrt{R_aC_aR_bC_b}} \quad ;$$

$$\text{since } \omega = 2\pi \text{ then } \omega_o = \frac{1}{\sqrt{R_aC_aR_bC_b}}$$

The transfer function (gain and phase shift Figure 4-3) of the frequency divider is:

$$\frac{E_1}{E_3} = \frac{1}{3 + j\left(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega}\right)}$$

At the operating frequency, $\omega = \omega_o$, therefore:

$$\frac{E_1}{E_3} = \frac{1}{3}$$

This means that at the operating frequency of the oscillator, one-third of the signal applied to the divider appears at the input to the amplifier. To sustain oscillations in any oscillator, a loop gain of unity is necessary, i.e., the gain from any one point in the circuit, around the loop and back to that same point, must be equal to one. Thus:

$$G_L = G_A \times \frac{E_1}{E_3} = 1$$

where

G_L = loop gain
G_A = amplifier gain
$\frac{E_1}{E_3}$ = divider gain

$$\text{Or:} \quad G_A = \frac{G_L}{E_1/E_3} = \frac{1}{1/3} = 3$$

The amplifier then, must have a gain of 3 to preserve unity gain in the loop and, therefore, to sustain oscillation at ω_o.

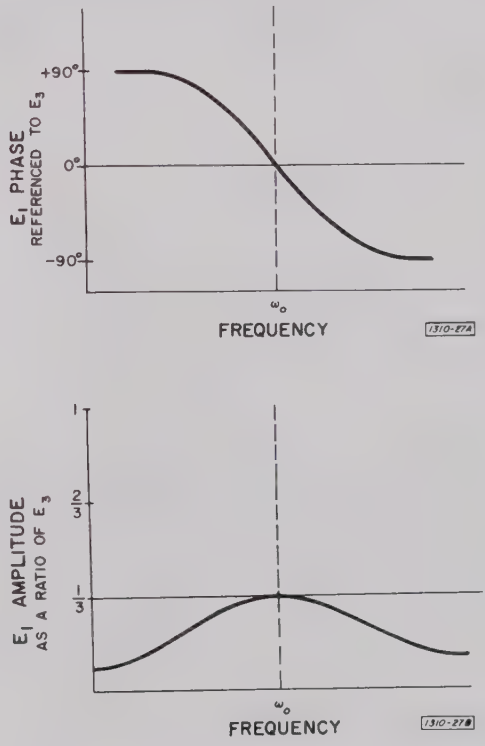

Figure 4-3. Typical transfer function of a Wien bridge.

4.2.3 Amplitude Stabilization. Figures 4-2, 4-4 and 4-5.

Under ideal conditions, the only requirement for stable oscillations is a constant loop gain of 1, i.e., if the amplifier gain and impedance-divider gain remained constant with changes in frequency, circuit parameters, and environment, only the frequency-determining impedance divider would be necessary. However, changes in frequency and environment affect the gain, phase, and terminal impedance of the amplifier and slight unbalances in C and R affect the gain (voltage ratio) of the divider. These factors change the loop gain and would cause the oscillator amplitude to increase or decrease.

For example, if these anomalies resulted in a momentary decrease in E_3, E_1 would decrease, further decreasing E_3, and so on until the amplitude became zero. Conversely if E_3 were to increase momentarily, E_1 would increase, further increasing E_3 until the amplifier saturated. This latter case can be easily demonstrated by removing the thermistor (R1) and monitoring the output. The output will be square waves instead of sinewaves and will not necessarily be at the frequency indicated by the frequency selectors.

To overcome this problem a divider R_1 and R_2 (Figure 4-2) is used. The input to the amplifier is the difference between the output of the two dividers. (E_2 is negative feedback and if it increases, E_3 decreases.) Note that the amplifier is across the bridge as is the detector/amplifier of any bridge.

The transfer function of the resistance divider is the simple voltage ratio:

$$\frac{E_2}{E_3} = \frac{R_2}{R_1 + R_2}$$

The loop gain is now:

$$G_L = G_A \left(\frac{E_1}{E_3} - \frac{E_2}{E_3} \right) \text{ or}$$

$$G_L = G_A \left[\frac{1}{3 + j\left(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega}\right)} - \frac{R_2}{R_1 + R_2} \right]$$

and must still be equal to 1 for stable amplitude.

In order to stabilize E_3 with changes in frequency and amplifier gain, a negative-temperature-coefficient thermistor is used for R_1. An ordinary resistor is linear, its resistance remains essentially constant as the current through it changes. But, the thermistor used in the Type 1316 is non-linear, its resistance decreases as the current through it increases.

To explain the action of the thermistor, the amplifier is shown as a current source (Figure 4-4) with a certain current-delivering capability represented by the constant voltage (+V) and a resistor (R_G).

Note that the same voltage, E_3, is across all three legs (impedance divider, resistance divider, and R_L):

$$E_3 = E_2 + E_4$$

$$E_2 = IR_2$$

$$E_4 = IR_1$$

When an ordinary resistor is used for R_1, the voltage drops across R_1 and R_2 change in direct proportion to the current through them, which in turn, changes in direct proportion to the gain (current-delivering capability) of the amplifier. In Figure 4-5, the result of increasing current (I), is shown. Since E_3 is the sum of E_2 and E_4, E_3 rises linearly as the gain of the amplifier rises.

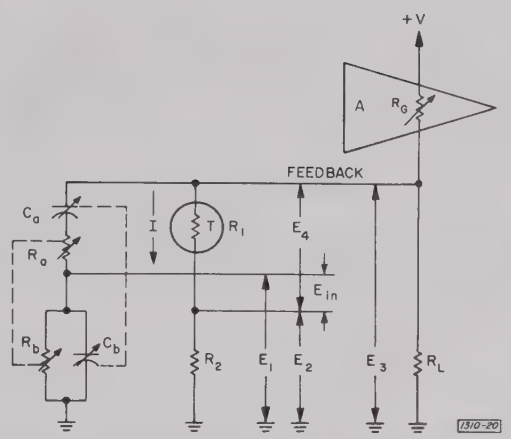

Figure 4-4. Schematic diagram of a typical Wien bridge showing the amplifier as a current source.

When a thermistor is used for R_1, and its resistance characteristic is chosen so that the slope of its IR drop is equal to the slope of the IR_2 drop, but of opposite sign, E_3 remains constant with changes in amplifier gain.

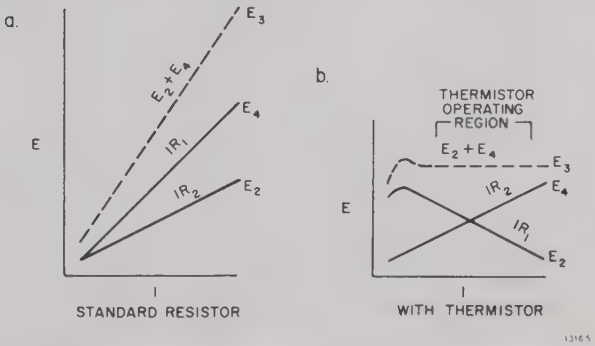

Figure 4-5. Graphical representation of the current (I) through R1: a. using a standard resistor; b. using a thermistor.

4.3 CIRCUIT DESCRIPTION.

4.3.1 General.

As previously mentioned, the heart of the 1316 circuitry is a modification of the Wien-bridge oscillator. The modification consist of a conductance-tuning method as opposed to resistance tuning. Para. 4.3.2 presents a basic circuit description of this oscillator in terms of conductance.

4.3.2 Modified Wien-Bridge Oscillator. Figure 4-1.

An incremental variation in the frequency of a Wien bridge oscillation may be effected by shunting the lower conductance arm of the bridge (G) by a variable conductance (g), whose value is variable between 0 and g. Since it is difficult, if not impractical, to reciprocally vary resistance

to infinite values, a variation in effective conductance can be produced by varying the effective voltage across it.

In this instrument α varies from 0 to 1, an easy task for a variable-voltage. The voltage across the conductance (g) is:

$$V - (1 - \alpha)\, V = \alpha V$$

$(1 - \alpha)V$ is derived from the voltage V at the negative input terminal of the oscillator amplifier (A1, Figure 4-1). The effective conductance (g) is:

$$\frac{I_g}{V_g} = \frac{\alpha V_g}{V} = \alpha g$$

If we sum G and αg and substitute into the equation for a Wien-bridge oscillator we have:

$$\omega_o = \sqrt{\frac{G(G + \alpha g)}{C^2}}$$

and by rearranging

$$\omega_o = \frac{1}{C} \sqrt{G^2 + \frac{G^2 \alpha g}{G}}$$

$$= \frac{1}{C} \sqrt{G^2 \left(1 + \frac{\alpha g}{G}\right)}$$

$$= \frac{G}{C} \sqrt{1 + \frac{\alpha g}{G}}$$

It can be shown that:

$$\sqrt{1 + \sigma} \approx 1 + \frac{\sigma}{2} \text{ when } \sigma << 1$$

and since $g << G$
then

$$\omega_o = \frac{G}{C} \sqrt{1 + \frac{\alpha g}{G}}$$

$$\simeq \frac{G}{C} \; 1 + \frac{\alpha g}{2G}$$

$$\simeq \frac{1}{C} \left(G + \frac{\alpha g}{2}\right)$$

From $\omega_o \approx 1/C\ (G + \alpha g/2)$ it can be seen that αg produces an incremental variation in the product ω_o. The value of the variable (α) is determined by A-R14, the least-significant-digit frequency selector. The term G is varied by means of parallel-resistor combinations selected by the first two frequency selectors, A-S3 and A-S4. Frequency range is determined by the value of C, which is selected by A-S5.

4.3.3 Output Power Amplifier.

The final output power from the instrument is transformer coupled from a class-B power amplifier consisting of Q13-Q18.

Signal from the oscillator section is amplitude controlled by the OUTPUT ADJUST control (A-R27) and applied to the base of the input-voltage amplifier Q13. The collector output of Q13 is applied to the base of Q14 and the collector circuit of this stage feeds the final output stages. The collector load of Q14 consists of R43 and R44; the junction is bootstrapped to the amplifier output via C35, to provide ac multiplication of the impedance of R43.

The two halves of the class-B output stage consist of composite states Q15-Q18. Each pair is connected as a high-input-impedance, unity-gain stage. Final output is provided by the collectors of Q17 and Q18. These two stages also drive the feedback divider R40 and R39, whose values are chosen to provide a closed-loop gain of 4.

Idle current in Q17 and Q18, necessary to minimize crossover distortion, is maintained by the voltage drop across CR11 and CR12. This voltage is equal to that across R47 and R48 plus the base-emitter drop of Q15 and Q16.

Diodes CR9, CR10, CR13, CR14, CR19, and CR20 provide protection from transients occurring during the oscillator start-up period.

R41, C34 and R42, C36 modify the high-frequency loop gain to maintain loop stability. R42 is variable to adjust the time constant of this network to compensate for variations in winding capacitance of the low-frequency transformer T2. This transformer has some effect on the high-frequency characteristics of the feedback loop.

4.3.4 Autotransformer Output.

One of three output transformers is used to couple the POWER OUTPUT jack to the power-amplifier output. Each transformer is tapped to provide a choice of voltage. T2 operates between 10-100 Hz, T3 between 100 Hz – 10 kHz and T4 between 10 kHz – 100 kHz. Resistance is added to the normal winding resistance to define the maximum short circuit current at each tap.

4.3.5 Meter Circuit.

If the gain of A (comprised of Q19-Q21) is large, V_{FB} (base of Q20) will be very close to V_{IN} (base of Q19) and the effect of the nonlinear characteristic of the rectifier at low levels will be very small. The half-cycle pulses of current, flowing through R61 and R62, set the g_m of system; the average value of the full-wave rectified pulses of current is indicated by the meter A-M1. The time constant of C42, & C43 and the meter resistance is long enough to permit steady readings at low frequencies.

4.3.6 Reference Outputs. **Figure 4-1.**

Two reference outputs (IN-PHASE and QUADRATURE) were built into the 1316 oscillator to facilitate its use with the double-phase-sensitive 1238 Detector.

The IN-PHASE output is derived directly from the oscillator output and is in-phase with the output voltage, disregarding phase errors in the power amplifier and output transformer. The QUADRATURE output lags the IN-PHASE output by 90° and is derived by sampling the current flowing through C_b (Figure 4-1).

By making the gain of A_3 large most of the input current is forced to flow through R_F. This provides an output voltage proportional to the input current. However, since the magnitude of I depends on the frequency setting and the value of C for the range in use, R_F must be varied with frequency to maintain a constant quadrature output. This is accomplished with conductance decades A-R102—A-R109, which are controlled with A-S3 and A-S4 respectively.

4.3.7 Power Supply.

Power for all sections of the oscillator is obtained from a regulated supply consisting of Q1, A-Q2, A-Q3, Q4 and Q5. The regulator is on the negative or return side of the supply.

A fraction of the output voltage is compared, via Q5, with the 6.8-V Zener-diode reference. The collector current of Q5 varies with the difference between the two voltages and is amplified by Q1. The current source (Q4) and the Darlington pair (A-Q2 and A-Q3) comprise the collector load of Q1. Variations of the voltage at the Darlington-pair input (AT5) cause the output voltage at WT10 to change in such a manner that any original error is vastly reduced.

4.4 SYNCHRONIZATION.

4.4.1 General.

The method used to synchronize the oscillator is commonly called injection locking and is the same mechanism that causes some oscillators to beat with the power-line frequency or to lock with it.

Injection locking is a natural extension of the normal oscillator operation and, except for an isolating resistor and capacitor, is dependent only upon the proper operation of the oscillator. The naturalness of the extension is apparent when it is realized that normal operation is, in fact, only an amplitude-regulated, frequency-selective regeneration of noise sources within the oscillator. Synchronization is an amplitude-regulated, frequency-selective regeneration of an externally applied signal.

There are three important characteristics associated with the use of the EXT SYNC feature:

a. Output.
b. Input synchronizing or phase locking.
c. Input-frequency selectivity or filtering.

These characteristics are discussed in the following paragraphs.

4.4.2 Output Characteristic.

A nominal 0.3-V rms output signal, behind 27 kΩ, is available from the EXT SYNC jack. The level of this sync output signal is independent of the output voltage controls or the output load. One side of the sync output is chassis ground and the signal is in phase with the POWER OUTPUT.

The sync output will drive any size load without increasing the oscillator distortion. However, only high-impedance loads are recommended where full frequency accuracy is required. The worst-case load, a short circuit, will decrease the frequency by 1 or 2%.

4.4.3 Input Synchronizing Characteristic.

The oscillator frequency can be synchronized or locked with any input signal that is applied to the EXT SYNC jack, if the oscillator is tuned to the approximate frequency of the input. The range of frequencies, over which this synchronization will take place, is a function of the amplitude of the frequency component to which the oscillator locks. It increases approximately linearly, and produces a lock range of approximately ±1% for each volt input.

The oscillator will maintain synchronization if either the oscillator frequency or the synchronizing frequency is changed, within the lock range. However, there is a time constant of about one second associated with the synchronizing mechanism. Thus, if the amplitude or frequency of the sync signal or the frequency setting of the oscillator is changed, there will be transient changes in amplitude and phase for a few seconds before the oscillator returns to steady-state synchronization.

This time constant is caused by the thermistor amplitude regulator as it readjusts to the different operating conditions. The thermistor is sensitive only to changes in average values of frequency or amplitude where the averaging time is in the order of seconds. Hence, frequency-modulated and amplitude-modulated sync signals, which have a constant average value of frequency and amplitude over a period of a second or less, are not affected by this time constant. They are affected by the equivalent time constant of the filter characteristic, discussed in para. 4.4.4.

For slow changes in frequency or amplitude, the lock range and the capture range are the same; i.e., the frequency or amplitude at which the oscillator goes from the synchronized state to the unsynchronized state is the same as when it goes from the unsynchronized state to the synchronized state. Synchronization is a true-phase-lock, because it maintains a constant phase difference between the sync input and the oscillator output. The phase difference is 180° when the dialed frequency is identical to

the sync frequency and approaches ±90° as the frequency approaches the limits of the lock range (see Figure 4-6). Note that the phase difference is also a function of the amplitude of the sync signal, because the lock range is a function of the amplitude.

The input impedance at the EXT SYNC jack is 27 kΩ at all frequencies except the synchronizing frequency. At the synchronizing frequency, the impedance, in general, is complex and can vary over a wide range, including negative values because the connector is also a source at the synchronizing frequency.

Since the connector is simultaneously a source and an input, care should be taken to ensure that the sync-output voltage does not interfere with the drive source. The high output impedance of the EXT SYNC jack makes it easy to minimize the sync-output signal. For example, if a 600-Ω source is used less than 20 mV will appear across the source.

4.4.4 Input Frequency Selectivity.

The RC network in the oscillator, used to determine the frequency of oscillation can also be used to filter signals applied externally. Signals applied to the EXT SYNC jack that are close to the frequency of synchronization will be amplified in the output, but those frequencies outside the lock range will be reduced. The intrinsic selectivity or Q, of this filter is constant and is determined only by the RC Wien network.

The voltage gain between the EXT SYNC jack and the OUTPUT jack is constant at any output level and output frequency, except the frequency of oscillation, regardless of the amplitude of the incoming signal.

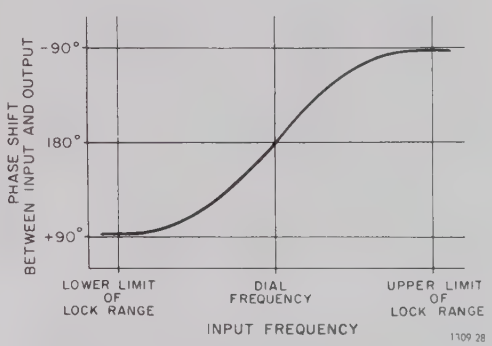

Figure 4-6. Phase shift over the lock range.

Service and Maintenance—Section 5

5.1 GR FIELD SERVICE 5-1
5.2 MINIMUM PERFORMANCE STANDARDS 5-1
5.3 ASSEMBLY/DISASSEMBLY PROCEDURES 5-5
5.4 MAJOR COMPONENTS 5-5
5.5 SERVICING THE ETCHED-CIRCUIT BOARD 5-5
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5.8 TROUBLE ANALYSIS 5-6

WARNING

Potentially lethal shock hazards exist in the circuitry inside. If troubleshooting is necessary, it should be performed by qualified personnel familiar with the hazard.

5.1 GR FIELD SERVICE.

The stated warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone the nearest GR service facility (see back page), giving full information of the trouble and of steps taken to remedy it. Describe the instrument by type number (front panel), serial, and ID numbers (rear panel).

Instrument Return. Before returning an instrument to General Radio for service, please ask our nearest office for a "Returned Material" number. Use of this number in correspondence and on a tag tied to the instrument will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

For return shipment, please use packaging that is adequate to protect the instrument from damage, i.e., equivalent to the original packaging. Advice may be obtained from any GR office.

5.2 MINIMUM PERFORMANCE STANDARDS.

5.2.1 General.

The equipment, methods, and criteria for verifying the specified performance of the oscillator are presented in the following paragraphs. Table 5-1 lists the necessary equipment and Figure 5-1 shows a typical setup for the service and maintenance checks.

5.2.2 Power-Circuit Check.

a. Connect the oscillator under test to a metered autotransformer set to 0-V.

b. Set the oscillator rear-panel power-selector slide switch to 100-125 V, and power switch on.

c. Slowly increase the line voltage to 115 V. The input power should be 5 W (nominal).

d. Connect the 1807 from AT3 to chassis. (See Figure 5-2).

e. Vary the line voltage from 100 to 125 V. The 1807 should read between 19.7 and 20.3 V dc.

f. Reset the line voltage to 115 V and maintain this voltage for all further checks.

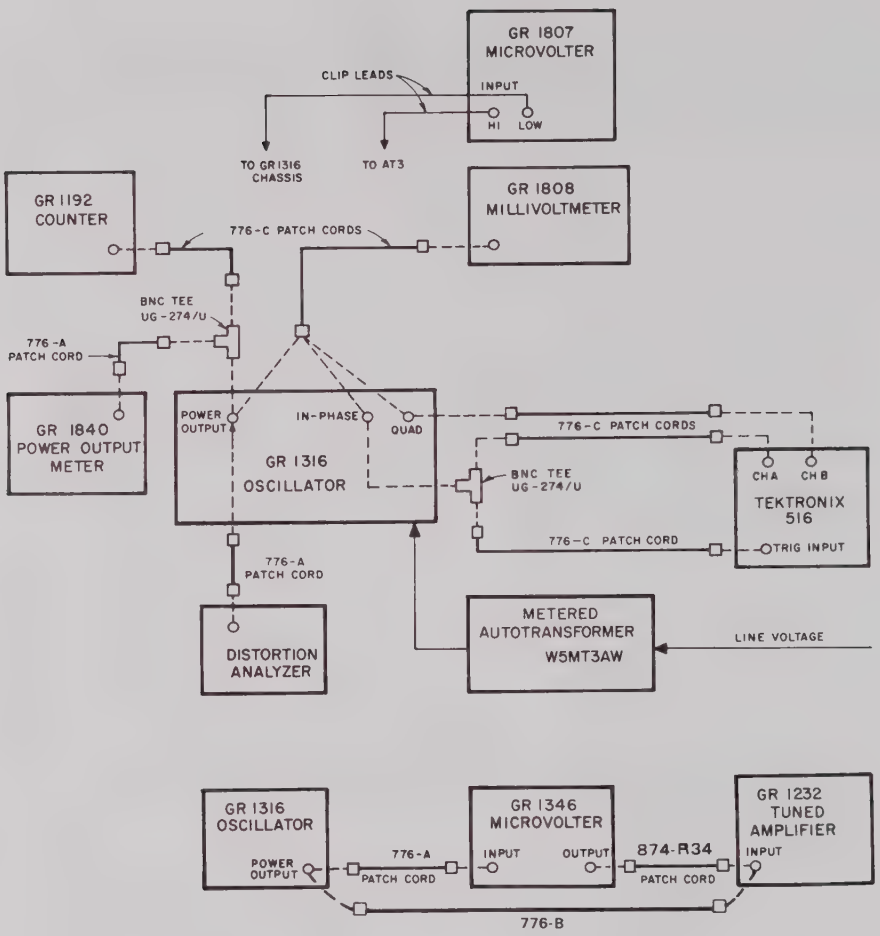

Figure 5-1. Test-equipment setup.

5.2.3 Frequency Accuracy and Range.

The output frequency of this oscillator is typically ±1% of the value set by the FREQUENCY selectors; the range is 10 Hz to 100 kHz. Following is a procedure that can be used to check both the accuracy and the range:

a. Connect INPUT A of the 1192 Counter to the POWER OUTPUT jack (Figure 5-1). Set the counter controls to measure period with a 100-μs gate time.

b. Set the 1316 controls as follows:

POWER switch	POWER
FREQUENCY Selectors	10.0 Hz
OUTPUT VOLTAGE RANGE control	.15
OUTPUT ADJUST Control	MAX

c. Observe the counter visual register. It should display a reading within the limits specified in Table 5-2.

d. Set the oscillator FREQUENCY selectors to 1kHz and adjust the counter controls to measure frequency.

e. Again observe the counter visual register and check Table 5-2 for the specified frequency limits.

5.2.4 Output-Voltage and Power Levels.

Output-Voltage Level. The following procedure can be used to check the oscillator output-voltage:

a. Set the oscillator controls as follows:

FREQUENCY SELECTORS	1 kHz
OUTPUT VOLTAGE RANGE	1.5 V
OUTPUT ADJUST	MAX

b. Set the Type 1808 AC Millivoltmeter to the 1.5-V range.

CAUTION

Make sure that the oscillator is set to the 1.5-V range before connecting the voltmeter.

c. Connect the Millivoltmeter to the POWER OUTPUT jack (Figure 5-1).

d. Observe the voltmeter indication — it should be ≧ 1.25 V.

Table 5-1

TEST EQUIPMENT

Item	Requirements	Recommended Type*
Counter	Range: 0.1 – 200 V, 10 Hz – 100 kHz	GR 1192
Dc Microvoltmeter	Range: up to 100 V, 1% accuracy	GR 1807
Ac Millivoltmeter	Range: 0.5 – 300 V, 1% accuracy	GR 1808
Power Meter	Range: 16 W, 40 Hz to 20 kHz	GR 1840
Oscilloscope	Bandwidth: 15 MHz Deflection factor: 5 V/cm	TEKTRONIX† 516 with Type 1A1 dual-trace plug-in unit.
Patch Cord	874 to 274	
Probe	X10, low capacitance	Tektronix P6008
Patch Cord	Double plug to BNC plug, 3 ft.	776-A
Patch Cord	874 to BNC	776-B
Patch Cord	BNC plug to BNC plug, 3 ft. (3)	776-C
Patch Cord	274 to 274, 3 ft.	274-NP
Tee	BNC each end	Type BNC (UG-274/U)
Tuned Amplifier and Null Detector	Range: 20 Hz – 2 kHz	GR 1232
Audio Frequency Microvolter	Output: 1 V, sensitivity: 15 μV min.	GR 1346
Distortion Meter	Distortion level down to 0.1%	HP 332
Metered Auto-transformer	Output Voltage: 0-140 V, single phase, 50-60 Hz	

*Or equivalent

†Registered trademark, Tektronix, Inc., Beaverton, Ore.

To check the other output-voltage ranges, adjust the 1808 voltmeter accordingly, and set the OUTPUT VOLTAGE RANGE switch to the desired range. The value indicated by the voltmeter should be as listed in Table 5-3.

Output Power Level. The following procedure can be used to check the output-power level:

a. Connect the Type 1840 Output Power Meter to the POWER OUTPUT jack. (Figure 5-1).

b. Adjust the power-meter controls to conform to any of the conditions depicted by the ***1840 Impedance*** and ***Nominal Output Power***, columns of Table 5-3.

c. Adjust the oscillator controls as follows:

FREQUENCY Selectors . . . . . 1 kHz
OUTPUT VOLTAGE RANGE . . . Desired Range
OUTPUT ADJUST . . . . . MAX

d. Observe the power-meter indications. They should be as listed in Table 5-3.

The lowest impedance obtainable from the 1840 is 0.6 Ω, which was suggested as the nominal load for the oscillator on its lowest-voltage range (Table 5-3). If the output impedance for this range is matched with 0.25 Ω, 1.6-W, out can be obtained.

5.2.5 Amplitude v Frequency Response.

The response (o.c.) should be constant within ±2% from 10 Hz – 50 kHz, for frequencies >50 kHz the specification is ±5%.

Table 5-2

OSCILLATOR OUTPUT-FREQUENCY-RANGE LIMITS

Frequency-Selectors Setting	Output-Frequency Limits
10 Hz	101 – 99ms
100 Hz	10.1 – 9.9ms
1 kHz	990 – 1010 Hz
10 kHz	9900 – 10100 Hz
100 kHz	99000 – 101000 Hz

Table 5-3

OUTPUT-VOLTAGE AND POWER LEVELS

Output V-Range	Open-Circuit Voltage	1840 Impedance	Nominal Output Power-W
1.5	≧ 1.25	0.6 Ω	0.66
5	≧ 4	2.5 Ω	1.6
15	≧ 12.5	25 Ω	1.6
50	≧ 40	250 Ω	1.6
150	≧ 125	2.5 kΩ	1.6

Following is a procedure that can be used to check the response:

a. Set the 1808 to the 15-V range.

b. Connect the 1808 to the oscillator POWER OUTPUT.

c. Set the oscillator frequency for 1 kHz and adjust the output voltage controls for 10-V out, as indicated by the 1808.

d. Set the oscillator frequency controls for any frequency within the oscillator range and note the 1808 voltage indication. It should be within ±2% of the voltage set in step c, for frequencies ≤50 kHz, ±5% for frequencies >50 kHz.

5.2.6 Hum.

The following procedure can be used to check for 60-Hz hum at the output of the power amplifier:

NOTE

This check must be made with the instrument in its cabinet.

a. Connect the instruments as shown in Figure 5-1.

b. Set the oscillator for a 1-V, 60 Hz output.

c. Set the Type 1346 Audio-Frequency-Microvolter controls as follows:

METER FULL SCALE . . . . . 1 V
FULL SCALE OUTPUT VOLTAGE . . . 10 mV
LEVEL . . . . . 10 (full scale)
OUTPUT Switch . . . . . ON

d. Set the Type 1232 Tuned-Amplifier-and-Null-Detector controls as follows:

METER Switch . . . . . LINEAR
FILTER FREQUENCY . . . . . 20-200 Hz
FILTER TUNING 6

e. Adjust the 1232 GAIN and FILTER-TUNING controls for a peak reading of 100 on the linear (black) scale. After this adjustment is completed the amplifier is calibrated for 10 mV full scale. ***Be careful not to change these control adjustments.***

f. Remove the 1346 from the setup.

g. Set the oscillator controls as follows:

FREQUENCY SELECTORS . . . . . 1 kHz
OUTPUT ADJUST . . . . . Fully ccw
OUTPUT VOLTAGE RANGE . . . . . 150 V

CAUTION

Before reconnecting the 1232, make sure that the oscillator OUTPUT ADJUST control is fully ccw.

h. Connect the oscillator POWER OUTPUT directly to the 1232 INPUT connector, with a 776-B Patch Cord.

i. The oscillator OUTPUT-VOLTAGE-RANGE control can now be set to any of its five positions and the corresponding hum voltage read from the 1232 meter. The voltages should not be greater than those specified in Table 5-4.

5.2.7 Distortion.

Output distortion can be checked by the following procedure:

a. Set the oscillator OUTPUT VOLTAGE RANGE and ADJUST controls for maximum output.

b. Connect the HP 332 Distortion Analyzer to the oscillator output as shown in Figure 5-1.

c. Adjust the analyzer controls to measure distortion.

d. Refer to the OUTPUT DISTORTION LIMITS curve contained in the specifications near the front of this manual. The measured value of distortion should conform to the curve.

Table 5-4

CALIBRATED 1232 MEASUREMENTS

Oscillator Voltage Range	Hum Voltage
150	4.5 mV
50.0	1.5 mV
15.0*	450 μV
5.0	150 μV
1.5	45 μV

*Recalibrate 1232 for 1mV full scale using 1346.

5.2.8 Reference Outputs.

Phase Relationship. The QUADRATURE output lags the IN-PHASE output by approximately 90°. Following is a method that can be used to check this phase relationship:

a. Connect the oscilloscope as shown in Figure 5-1.

b. Adjust the scope controls as follows:

TRIGGERING SELECTOR . . . . . AUTO
TIME/CM . . . . . 1 ms
CH A VOLTS/CM 10
CH B VOLTS/CM 10

c. Set the oscillator controls for any output.

d. Using the position controls, position the scope pattern so that the graticule can be used as a reference.

e. Observe the scope pattern carefully. Notice that the QUADRATURE output lags the IN-PHASE output by approximately 90°.

Output Level. The open-circuit outputs at the REFERENCE OUTPUTS jacks are constant over the range of the oscillator. Following is a procedure that can be used to check the level of these outputs:

a. Set the oscillator controls for any output.

b. Connect the 1808 Millivoltmeter to the IN-PHASE output.

c. Adjust the voltmeter controls to measure 1.5 V, ac.

d. Observe the voltmeter indication — it should be 1.25 ± 0.25 V.

To measure the QUADRATURE output level, connect the 1808 to the QUADRATURE output and repeat steps b-d above.

Output Distortion. To make output distortion checks of the REFERENCE OUTPUTS, use the same procedure presented in para. 5.2.7 with one exception. The distortion analyzer is connected to either the IN-PHASE or QUADRATURE output jack.

Amplitude v Frequency Response. With the exception of step b, para 5.2.5 can be used to make response checks of the REFERENCE OUTPUTS. Regarding step b, the 1808 must be connected to either the IN-PHASE or the QUADRATURE output jack, depending on which is being checked.

The output level for both outputs is 1.25 ± 0.25 V and the measuring equipment will have to be adjusted accordingly.

5.3 ASSEMBLY/DISASSEMBLY PROCEDURES.

5.3.1 Knob Removal.

CAUTION

Do not use a screwdriver or other tool to pry off the knob if it is tight. Do not lose the spring clip in the knob while it is off.

To remove the knob from a front-panel control, to replace a damaged knob or the associated control, proceed as follows:

a. Grasp the knob firmly with dry fingers, close to the panel, and pull the knob straight away.

b. Observe the position of the setscrew in the bushing when the control is fully ccw.

c. Release the setscrew with a 5/64-in. Allen wrench; pull the dial/bushing off the shaft.

d. Remove and retain the black felt washer, behind the dial/knob assembly (FREQUENCY controls only).

NOTE

To separate the bushing from the knob, if for any reason they should be combined off of the shaft, drive a machine tap a turn or two into the bushing to provide sufficient grip for easy separation. If the retention spring in the knob falls out, reinstall it in the interior notch with the small slit in the inner diameter of the wall.

5.3.2 Knob Installation.

To install a knob assembly on the control shaft:

a. Place the black felt washer over the control shaft.

b. Mount the dial bushing on the shaft.

c. Orient the setscrew properly on the bushing, with respect to step b in para. 5.3.1 and lock the setscrew with an Allen wrench.

NOTE

If the end of the shaft protrudes through the bushing, the knob cannot seat properly.

d. Place the knob on the bushing with the retention spring opposite the setscrew.

e. Push the knob in until it bottoms and pull it slightly to check that the retention spring is seated in the groove in the bushing.

5.4 MAJOR COMPONENTS.

Figure 5-2 identifies the major components of the oscillator with their corresponding locations.

5.5 SERVICING THE ETCHED-CIRCUIT BOARD.

The 1316 Oscillator has one etched-circuit board.

When removing or replacing parts, use a low-heat soldering iron and a small-diameter rosin-core solder. Do not subject the parts or board to excessive or prolonged heat. If a part is obviously faulty or damaged, clip the leads close to the part and then remove the leads from the circuit side.

5.6 CALIBRATION PROCEDURES.

5.6.1 General.

Calibrate the oscillator whenever minimum performance standards, operating procedures, trouble analysis, or maintenance checks indicate that the instrument is out of calibration.

5.6.2 Power-Supply Adjustment.

To adjust the power-supply, B+ voltage, connect the 1807 between TP3 (Figure 5-2) and the chassis for a dc measurement. Use a pair of short clip leads. Adjust R11 for a reading of 20 V.

5.6.3 Frequency Stability.

Following is a frequency-stability adjustment procedure:

a. Set the oscillator controls as follows:

FREQUENCY Selectors	50 Hz*
OUTPUT VOLTAGE RANGE	150 V
OUTPUT ADJUST	0

b. Connect a short across the POWER OUTPUT. (Use a short clip lead.)

*The third digit must be set to the detented zero-position.

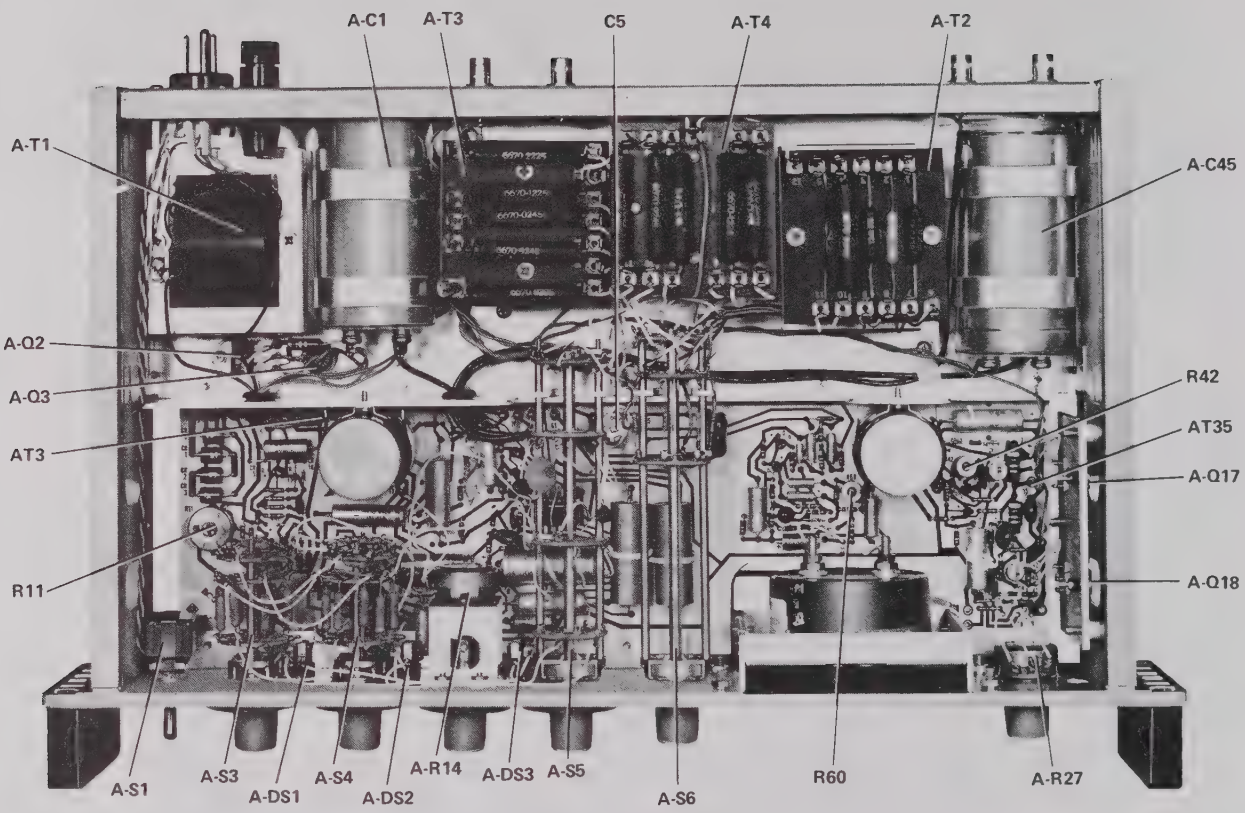

Figure 5-2. Top, interior view.

c. Connect the oscilloscope probe to AT35 (Figure 5-2).

d. Set the OUTPUT ADJUST control to MAX.

e. Adjust the oscilloscope controls to obtain a sinewave pattern; observe the pattern carefully for aberrations of the signal.

f. Adjust R42 (Figure 5-2) to eliminate the aberrations.

g. Rotate the FREQUENCY range selector from the Hz to the kHz position. Slightly readjust R42 to eliminate any aberrations that reappear

5.6.4 Meter Accuracy.

The meter accuracy can be adjusted by the following procedure:

a. Set the oscillator controls for a 100-V, 1-kHz output.

b. Set the 1808 to the 150-V range and connect it to the oscillator POWER OUTPUT.

c. Adjust the OUTPUT ADJUST control for a 100-V indication on the 1808.

d. Adjust R60 (Figure 5-2) so that the panel-meter indication is the same as that of the 1808 ±1%.

5.6.5 Frequency Accuracy.

The highest frequency range is adjusted with the variable capacitor C5. All other ranges are adjusted with fixed-value capacitors chosen at the factory.

Following is a recommended adjustment procedure for the highest frequency range:

a. Set the oscillator controls for a 4-V, 50-kHz output.

b. Adjust the counter controls to measure frequency and connect it to the oscillator POWER OUTPUT.

c. Adjust C5 to obtain a counter reading of 50.02 kHz.

5.7 GENERAL MAINTENANCE.

5.7.1 Lamp Replacement.

To replace the decimal-point lamps, slide the metal clip off the back of the metal holder and remove the lamp. Insert a new lamp (Chicago Miniature Lamp Works, No. 327 or equivalent), and replace the clip.

5.7.2 Panel Finish.

If the front panel becomes marred or scratched, retouch with a light gray paint that conforms with the Federal Standard 595 (gray, 26492).

5.8 TROUBLE ANALYSIS.

5.8.1 General.

Isolating a symptom to a particular circuit can be done by checking for the presence or absence of signals at the rear-panel output jacks. For example, if the instrument controls are adjusted for a 10.0 kHz, 10-V output, the

front-panel-meter indication should be 10 V. If there is no indication, check the POWER OUTPUT. A voltage here indicates a problem in the meter circuit. If no voltage is present, check the IN-PHASE output. There should be 1.25 ±0.25 V present regardless of the frequency and voltage-control settings. The correct voltage indicates a problem in the output power amplifier. An incorrect voltage indicates an oscillator or power-supply problem. The decimal-point lamps are connected directly to B+; therefore, if they are on the power supply is working.

The next step should be to check resistance and/or voltages within the circuit suspected of having a malfunction. A functional block diagram (Figure 4-1) and the schematic diagram (Figure 5-5) are supplied as an aid for localizing problems.

5.8.2 Incorrect Output Frequency.

An incorrect output frequency should be isolated to a particular range, and if possible, to a particular step within a range. If the output is incorrect for one of the frequency ranges, the capacitors for that range should be checked. If the output is incorrect for a step within one of the ranges, the resistors for that step should be checked. (Refer to the schematic diagram Figure 5-3.)

5.8.3 Incorrect Output Voltage.

If the POWER OUTPUT voltage is incorrect, check the IN-PHASE output jack to be 1.25 ± 0.25 V, rms. An incorrect voltage at this jack indicates either a power-supply or an oscillator problem. The next step should be to check the 20-V, B + voltage. If it is incorrect, the problem can be isolated by making resistance and voltage checks in the power supply. If it is correct, the problem is in the oscillator and the first component to suspect is the thermistor.

A correct IN-PHASE, output voltage indicates that the problem is between the power-amplifier input and the output from the instrument. Therefore, check the voltage at AT35 to be approximately 5 V, rms. An incorrect voltage here indicates output-power-amplifier problems. A correct voltage indicates an output-transformer or power resistor problem. (Refer to the schematic diagram Figure 5-3.)

5.8.4 Excessive Distortion.

If there is excessive distortion at the POWER OUTPUT, check the IN-PHASE output. (Refer to the OUTPUT DISTORTION LIMITS curve contained in the specifications near the front of this manual.) Excessive distortion here indicates that the problem is in the oscillator and is probably caused by the thermistor (R23). Otherwise the problem is probably caused by a defective component in the power amplifier.

5.8.5 Excessive Hum.

If the hum specification is exceeded at the POWER OUTPUT, the B + voltage should be checked for ripple. Ripple voltages > 100 mV pk-pk can contribute to excessive hum. Components to suspect are filter capacitors C1, C4, and CR1–CR4.

5.8.6 Low Output from EXT SYNC.

The most common cause of a low EXT-SYNC output is capacitance loading of the signal. Output impedance is 47 kΩ; therefore 100 pF across the output (e.g. about 3 ft. of shielded cable) will reduce the output at the higher frequencies. If this condition creates a problem, a shorter patch cord should be used.

5.8.7 Meter Window Care

The clear acrylic meter window can become susceptible to electrostatic-charge buildup and can be scratched, if improperly cleaned.

It is treated inside and out in manufacturing with a special non-abrasive anti-static solution, Statnul*, which normally should preclude any interference in meter operation caused by electrostatic effects. The problem is evidenced by the inability of the meter movement to return promptly to a zero reading, once it is deenergized. As supplied, the meter should return to zero reading within 30 seconds, immediately following the placement of a static charge, as by rubbing the outside surface. This meets the requirements of ANSI standard C39.1-1972.

If static-charge problems occur, possibly as the result of frequent cleaning, the window should be carefully polished with a soft dry cloth, such as cheesecloth or nylon chiffon. Then, a coating of Statnul should be applied with the polishing cloth.

*Available from Mancib Co., Burlington, MA 01803

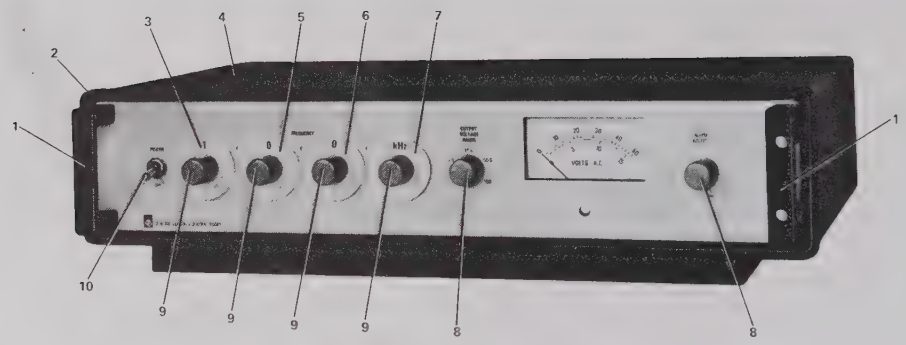

Figure 5-3. Mechanical parts, front view.

MECHANICAL PARTS LIST

Fig Ref	Qnt	Description	GR Part No.	Fed Mfg Code	Mfg Part No.
FRONT VIEW					
1.	2	Handle	5360-2007	24655	5360-2007
2.	1	Cabinet gasket	5331-2156	24655	5331-2156
3.	1	Dial asm., FREQUENCY	1864-1213	24655	1864-1213
4.	1	Bench cabinet asm. complete:	4172-4015	24655	4172-4015
	1	Bench cabinet asm.	4172-2042	24655	4172-2042
	1	Base asm.	4171-1021	24655	4171-1021
	1	Foot	4171-7010	24655	4171-7010
5.	1	Dial asm., FREQUENCY	5120-2440	24655	5120-2440
6.	1	Dial asm., FREQUENCY	1864-1230	24655	1864-1230
7.	1	Dial asm., Range	5120-2450	24655	5120-2450
8.	2	Knob asm., OUTPUT ADJUST; OUTPUT VOLTAGE RANGE, including retainer 5220-5402	5520-5221	24655	5520-5221
9.	4	Knob asm., FREQUENCY, including retainer 5220-5402	5520-5220	24655	5520-5220
10.	1	Toggle switch, A-S1, POWER/OFF	7910-1300	04009	83053-SA

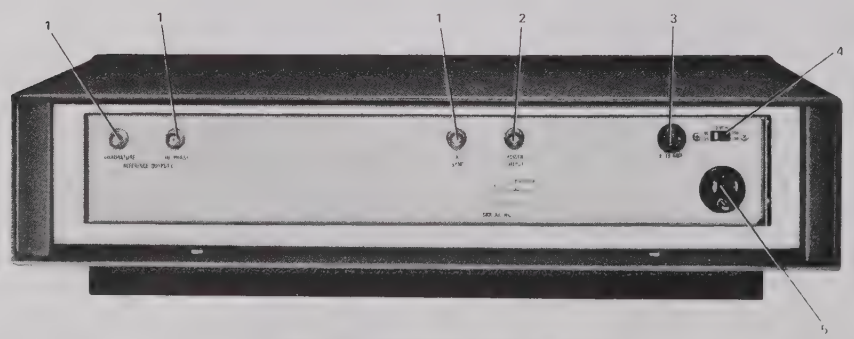

Figure 5-4. Mechanical parts, rear view.

MECHANICAL PARTS LIST

Fig Ref	Qnt	Description	GR Part No.	Fed Mfg Code	Mfg Part No.
REAR VIEW					
1.	3	Connector, A-J3, QUADRATURE; A-J4, IN-PHASE; A-J2, EXT SYNC.	4230-2300	81349	UG-1094/U
2.	1	Connector, A-J1, POWER OUTPUT	4230-2301	09408	UG-1094A/U
3.	1	Fuse mounting device	5650-0100	71400	HKP-H
4.	1	Slide switch, A-S2, LINE VOLTAGE SELECTOR	7910-0832	82389	11A-1118
5.	1	Connector, power plug, A-J5	4240-0210	24655	4240-0210

PRINTED CIRCUIT BOARD P/N 1316-4700

REFDES	DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
R 3	RES COMP 110 OHM 5PCT 1/4W	6099-1115	81349	RCR07G111J
R 4	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R 5	RES COMP 22 K 5PCT 1/4W	6099-3225	81349	RCR07G223J
R 6	RES COMP 200 K OHM 5PCT 1/4W	6099-4205	81349	RCR07G204J
R 7	RES COMP 47 OHM 5PCT 1/4W	6099-0475	81349	RCR07G470J
R 8	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R 9	RES COMP 6.8 K 5PCT 1/4W	6099-2685	81349	RCR07G682J
R 10	RES COMP 2.2 K 5PCT 1/4W	6099-2225	81349	RCR07G222J
R 11	POT WW TRM 1K OHM 10 PCT 1T	6056-0138	24655	6056-0138
R 12	RES COMP 4.3 K OHM 5PCT 1/4W	6099-2435	81349	RCR07G432J
R 15	RES COMP 2.2 K 5PCT 1/4W	6099-2225	81349	RCR07G222J
R 16	RES COMP 12 K 5PCT 1/4W	6099-3125	81349	RCR07G123J
R 17	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 18	RES COMP 56 K 5PCT 1/4W	6099-3565	81349	RCR07G563J
R 19	RES COMP 27 K 5PCT 1/4W	6099-3275	81349	RCR07G273J
R 20	RES FLM 249 OHM 1 PCT 1/4W	6350-0249	81349	RN60D2490F
R 21	RES COMP 3.9 K 5PCT 1/4W	6099-2395	81349	RCR07G392J
R 22	RES COMP 27 OHM 5PCT 1/4W	6099-0275	81349	RCR07G270J
R 23	THERMISTOR 40K OHM 20PCT	6740-1400	15801	BA-44V3
R 24	RES COMP 3.0 K OHM 5PCT 1/4W	6099-2305	81349	RCR07G302J
R 25	RES COMP 820 OHM 5PCT 1/4W	6099-1825	81349	RCR07G821J
R 26	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R 28	RES COMP 4.7 K 5PCT 1/4W	6099-2475	81349	RCR07G472J
R 29	RES COMP 680 OHM 5PCT 1/4W	6099-1685	81349	RCR07G681J
R 30	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 31	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 32	RES COMP 51 OHM 5PCT 1/4W	6099-0515	81349	RCR07G510J
R 34	RES COMP 2.0 K OHM 5PCT 1/4W	6099-2205	81349	RCR07G202J
R 35	RES COMP 2.2 K 5PCT 1/4W	6099-2225	81349	RCR07G222J
R 36	RES COMP 6.8 K 5PCT 1/4W	6099-2685	81349	RCR07G682J
R 37	RES COMP 43 K OHM 5PCT 1/4W	6099-3435	81349	RCR07G433J
R 38	RES COMP 51 K OHM 5PCT 1/4W	6099-3515	81349	RCR07G513J
R 39	RES COMP 100 OHM 5PCT 1/4W	6099-1105	81349	RCR07G101J
R 40	RES COMP 300 OHM 5PCT 1/4W	6099-1305	81349	RCR07G301J
R 41	RES COMP 4.7 OHM 5PCT 1/4W	6099-9475	81349	RCR07G4R7J
R 42	POT CERM TRM 500 OHM 10 PCT 1T	6049-0214	01121	SV5011
R 43	RES COMP 750 OHM 5PCT 1/4W	6099-1755	81349	RCR07G751J
R 44	RES COMP 750 OHM 5PCT 1/4W	6099-1755	81349	RCR07G751J
R 45	RES COMP 100 OHM 5PCT 1/4W	6099-1105	81349	RCR07G101J
R 46	RES COMP 100 OHM 5PCT 1/4W	6099-1105	81349	RCR07G101J
R 47	RES WW MOLDED .47 OHM 10 PCT 2W	6760-8479	75042	BWH 0.47 OHM 10PCT
R 48	RES WW MOLDED .47 OHM 10 PCT 2W	6760-8479	75042	BWH 0.47 OHM 10PCT
R 49	RES FLM 2.03K 1/2PCT 1/8W	6251-1203	81349	RN55D2031D
R 50	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 51	RES COMP 130 K OHM 5PCT 1/4W	6099-4135	81349	RCR07G134J
R 52	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 53	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R 54	RES COMP 7.5 K OHM 5PCT 1/4W	6099-2755	81349	RCR07G752J
R 55	RES COMP 51 K OHM 5PCT 1/4W	6099-3515	81349	RCR07G513J
R 56	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R 57	RES COMP 100 K 5PCT 1/4W	6099-4105	81349	RCR07G104J
R 58	RES COMP 3.0 K OHM 5PCT 1/4W	6099-2305	81349	RCR07G302J
R 59	RES COMP 12 K 5PCT 1/4W	6099-3125	81349	RCR07G123J
R 60	POT CERM TRM 10K OHM 10 PCT 1T	6049-0218	01121	SV1031
R 61	RES COMP 3.9 K 5PCT 1/4W	6099-2395	81349	RCR07G392J
R 62	RES COMP 3.9 K 5PCT 1/4W	6099-2395	81349	RCR07G392J
R 63	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 64	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 110	RES COMP 2.0 K OHM 5PCT 1/4W	6099-2205	81349	RCR07G202J
R 111	RES COMP 2.2 K 5PCT 1/4W	6099-2225	81349	RCR07G222J
R 112	RES COMP 200 OHM 5PCT 1/4W	6099-1205	81349	RCR07G201J
R 113	RES COMP 200 OHM 5PCT 1/4W	6099-1205	81349	RCR07G201J
R 114	RES COMP 100 OHM 5PCT 1/4W	6099-1105	81349	RCR07G101J
R 115	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
R 116	RES COMP 1.0 K 5PCT 1/4W	6099-2105	81349	RCR07G102J
AR 150	RES COMP 2.7 OHM 5PCT 1/4W	6099-9275	81349	RCR07G2R7J
AR 151	RES COMP 2.7 OHM 5PCT 1/4W	6099-9275	81349	RCR07G2R7J

FEDERAL SUPPLY CODE FOR MANUFACTURERS

From Defense Logistics Agency Microfiche

H4-2 SB 708-42 GSA-FSS H4-2

Ref FMC Column in Parts Lists

Code	Manufacturer
00136	McCoy Elctrns.,Mt.Holly Springs,PA 17065
00192	Jones Mfg.,Chicago,IL 60181
00194	Walsco Elctrns.,Los Angeles,CA 90018
00327	Welwyn Intntl.,Westlake,OH 44145
00434	Schweber Elctrns.,Westburg,NY 11590
00656	Aerovox.,New Bedford,MA 02745
00779	AMP Inc.,Harrisburg,PA 17105
01009	Alden Products.,Brockton,MA 02413
01121	Allen Bradley.,Milwaukee,WI 53204
01255	Litton Inds.,Beverly Hills,CA 90213
01281	TRW.,Lawndale,CA 90260
01295	TI.,Dallas,TX 75222
01526	GE.,Waynesboro,VA 22980
01930	Amerock.,Rockford,IL 61101
01963	Cherry Elctrc.,Waukegan,IL 60085
02111	Spectrol Elctrns.,City of Industry,CA 91745
02114	Ferroxcube.,Saugerties,NY 12477
02606	Fenwall Lab.,Morton Grove,IL 60053
02639	GE.,Schenectady,NY 12307
02660	Amphenol.,Broadview,IL 60153
02735	RCA.,Somerville,NJ 08876
02768	Fastex.,Desplains,IL 60016
03042	Carter Ink.,Cambridge,MA 02142
03508	GE.,Syracuse,NY 13201
03550	Vanguard Elctrns.,Inglewood,CA 90302
03636	Grayburne.,Yonkers,NY 10701
03877	Transitron Elctrns.,Wakefield,MA 01880
03888	KDI Pyrofilm.,Whippany,NJ 07981
03911	Clairex.,New York,NY 10001
04009	Arrow Hart.,Hartford,CT 06106
04643	Digitronics.,Albertson,NY 11507
04713	Motorola.,Phoenix,AZ 85008
04919	Component Mfg.,W.Bridgewater,MA 02379
05079	Tansistor Elctrns.,Bennington,VT 05201
05245	Corcom.,Chicago,IL 60639
05276	ITT Elctrns.,Pomona,CA 91766
05402	Controls Co.of Amer.,Melrose Pk,IL 60160
05574	Viking Inds.,Chatsworth,CA 91311
05624	Barber Colman.,Rockford,IL 61101
05748	Barnes Mfg.,Mansfield,OH 44901
05820	Wakefield Eng.,Wakefield,MA 01880
06383	Panduit.,Tinley Pk,IL 60477
06406	Truelove & Maclean.,Waterbury,CT 06708
06665	Precision Monolith.,Santa Clara,CA 95050
06743	Clevite.,Cleveland,OH 44110
06795	WLS Stamp.,Cleveland,OH 44104
06915	Richco Plstc.,Chicago,IL 60646
06928	Teledyne Kntcs.,Soland Bch,CA 92075
06978	Aladdin Elctrns.,Nashville,TN 37210
07047	Ross Milton.,Southampton,PA 18966
07126	Digitran.,Pasadena,CA 91105
07127	Eagle Signal.,Baraboo,WI 53913
07233	Cinch Graphik.,City of Industry,CA 91744
07263	Amet.,Culver City,CA 90230
07263	Fairchild.,Mountain View,CA 94040
07387	Birtcher.,N.Los Angeles,CA 90032
07595	Amer.Semicond.,Arlington Hts,IL 60004
07699	Magnetic Core.,Newburgh,NY 12550
07707	USM Fastener.,Shelton,CT 06484
07828	Bodine.,Bridgeport,CT 06605
07829	Bodine Elctrc.,Chicago,IL 60618
07910	Cont Device.,Hawthorne,CA 90250
07983	State Labs.,New York,NY 10003
07999	Borg Inst.,Delavan,WI 53115
08524	Deutsch Fastener.,Los Angeles,CA 90045
08556	Bell Elctrc.,Chicago,IL 60632
08730	Vemaline Prod.,Franklin Lakes,NJ 07417
09213	GE.,Buffalo,NY 14220
09353	C&K Components.,Watertown,MA 02172
09408	Star-Tronics.,Georgetown,MA 01830
09823	Burgess Battery.,Freeport,IL 61032
09856	Fenwal Elctrns.,Framingham,MA 01701
09922	Burndy.,Norwalk,CT 06852
10025	Glasseal Prod.,Linden,NJ 07036
10389	Chicago Switch.,Chicago,IL 60647
11236	CTS of Berne.,Berne,IN 46711
11599	Chandler Evans.,W.Hartford,CT 06101
11983	Nortronics.,Minneapolis,MN 55427
12040	National.,Santa Clara,CA 95051
12045	Elctrc Transistors .,Flushing,NY 11354
12498	Teledyne ,Mountain View,CA 94043
12617	Hamlin ,Lake Mills,WI 53551
12672	RCA .,Woodbridge,NJ 07095
12697	Clarostat ,Dover,NH 03820
12856	Micrometals.,City of Industry,CA 91744
12954	Dickson Elctrns .,Scottsdale,AZ 85252
12969	Unitrode .,Watertown,MA 02172
13094	Electrocraft.,Hopkins,MN 55343
13103	Thermalloy .,Dallas,TX 75234
13148	Vogue Inst.,Richmond Hill,NY 11418
13150	Vernitron.,Laconia,NH 03246
13327	Solitron Devices ,Tappan,NY 10983
13715	Fairchild.,San Rafael,CA 94903
13919	Burr Brown.,Tucson,AZ 85706
14010	Anadex Inst.,Van Nuys,CA 91406
14195	Elctrc Controls.,Wilton,CT 06897
14196	American Labs .,Fullerton,CA 92634
14332	Relton ,Arcadia,CA 91006
14433	ITT ,W Palm Beach,FL 33402
14482	Watkins & Johnson .Palo Alto,CA 94304
14608	Corbin ,Berlin,CT 06037
14655	Cornell Dubilier.,Newark,NJ 07101
14674	Corning Glass ,Corning,NY 14830
14749	Acopian ,Easton,PA 18042
14752	Electrocube ,San Gabriel,CA 91776
14889	R&G Sloan ,Sun Valley,CA 91352
14906	Elctrc Inst & Spclty ,Stoneham,MA 02180
14936	General Inst ,Hicksville,NY 11802
15238	ITT .,Lawrence,MA 08142
15476	Digital Equip ,Maynard,MA 01754

Code	Manufacturer
15605	Cutler Hammer .,Milwaukee,WI 53202
15782	Houston Inst.,Bellaire,TX 77401
15801	Fenwal Elctrns.,Framingham,MA 01701
15819	Sinclair & Rush .,St.Louis,MO 63111
16037	Spruce Pine Mica .,Spruce Pine,NC 28777
16068	Intntl Diode .,Jersey City,NJ 07304
16179	Omni Spectra .,Farmington,MI 48024
16301	Astrolab .,Linden,NJ 07036
16352	Codi .,Fairlawn,NJ 07410
16485	Sterling Inst .,New Hyde Park,NY 11040
16636	Indiana General .,Oglesby,IL 61348
16758	Delco .,Kokomo,IN 46901
16950	Precision Dynamics .,Burbank,CA 91504
16952	Amer Micro Devices .,Summerville,SC 29483
17117	Elctrc Molding .,Woonsocker,RI 02895
17540	Mohawk Spring .,Schiller Park,IL 60176
17745	Angstrohm Precsn .,Hagerstown,MD 21740
17771	Singer .,Somerville,NJ 08876
17850	Zeltex .,Concord,CA 94520
17856	Siliconix .,Santa Clara,CA 95054
18324	Signetics .,Sunnyvale,CA 94086
18542	New Prod Eng .,Wabash,IN 46992
18677	Scanbe .,El Monte,CA 91731
18736	Computer Diode .,S.Fairlawn,NJ 07936
18795	Cycon .,Sunnyvale,CA 94086
18911	Durant .,Watertown,WI 53094
19178	Zero .,Monson,MA 01057
19209	GE .,Gainesville,FL 32601
19373	Eastron .,Haverhill,MA 01830
19396	Paktron .,Vienna,VA 22180
19617	Cabtron .,Chicago,IL 60622
19644	LRC Elctrns .,Horseheads,NY 14845
19701	Electra .,Independence,KS 67301
20093	Elect Inds .,Murray Hill,NJ 07974
20754	KMC .,Long Valley,NJ 07853
21335	Fafnir Bearing .,New Britian,CT 06050
21688	Raytheon .,Norwood,MA 02062
21759	Lenox Fugle .,Watchung,NJ 07060
22526	Berg Elctrcs .,New Cumberland,PA 17070
22589	Electro Space Fabrctrs .,Topton,PA 19562
22753	UID Elctrcs .,Hollywood,FL 33022
23338	Wavetek .,San Diego,CA 92112
23342	Avnet Elctrcs .,Franklin Park,IL 60131
23936	Pamotor .,Bulingham,CA 94010
24351	Indiana Gnrl Elctrc .,Keasby,NJ 08832
24355	Analog Devices .,Cambridge,MA 02142
24444	General Semicond .,Tempe,AZ 85281
24446	GE .,Schenectady,NY 12305
24454	GE .,Syracuse,NY 13201
24455	GE .,Cleveland,OH 44112
24602	EMC Technlgy .,Cherry Hill,NJ 08034
24655	Gen Rad .,Concord,MA 01742
24759	Lenox Fugle .,S.Plainfield,NJ 07080
25008	Vactite .,Berkeley,CA 94710
25289	EG&G .,Bedford,MA 01730
26601	Tri-County Tube .,Nunda,NY 14517
26805	Omni Spectra .,Waltham,MA 02154
26806	American Zettler .,Costa Mesa,CA 92626
27014	National .,Santa Clara,CA 95051
27545	Hartford Universal Ball .,Rocky Hill,CT 06067
28480	HP .,Palo Alto,CA 94304
28520	Heyman Mfg .,Kenilworth,NJ 07033
28875	IMC Magnetics .,Rochester,NH 03867
28959	Hoffman Elctrcs .,El Monte,CA 91734
30043	Solid State Devices .,LaMirada,CA 90638
30646	Beckman Inst .,Cedar Grove,NJ 07009
30874	IBM .,Armonk,NY 10504
30985	Permag Magnetics .,Toledo,OH 43609
31019	Solid State Scntfc .,Montgomerville,PA 18936
31514	Standford Appld Engs .,Costa Mesa,CA 92626
31814	Analogic .,Wakefield,MA 01880
31951	Trirdge .,Pittsburgh,PA 15231
32001	Jensen .,Chicago,IL 60638
33095	Spectrum Control .,Fairview,PA 16415
33173	GE .,Owensboro,KY 42301
34141	Koehler .,Marlboro,MA 01752
34156	Semicoa .,Costa Mesa,CA 92626
34333	Silicon Genrl .,Westminster,CA 92683
34335	Advanced Micro Devices .,Sunnyvale,CA 94086
34649	Intel .,Santa Clara,CA 95051
34671	Solitron Devices .,Jupiter,FL 33458
35929	Constanta .,Montreal,QUE,CAN
36462	National Ltd .,Montreal,QUE,CAN
37942	Mallory .,Indianapolis,IN 46206
38443	Marlin Rockwell .,Jamestown,NY 14701
39317	McGill Mfg .,Valparaiso,IN 46383
40931	Honeywell .,Minneapolis,MN 55408
42190	Muter .,Chicago,IL 60638
42498	National .,Melrose,MA 02176
43334	New Departure-Hyatt .,Sandusky,OH 44870
43991	Norma Hoffman .,Stanford,CT 06904
49671	RCA .,New York,NY 10020
49956	Raytheon .,Waltham,MA 02154
50088	Mostek .,Carrollton,TX 75006
50101	GHZ Devices .,S.Chelmsford,MA 01824
50507	Micro Networks .,Worcester,MA 01606
50522	Monsanto .,Palo Alto,CA 94304
50721	Datel Systems .,Canton,MA 02021
51167	Aries Elctrcs .,Frenchtown,NJ 08825
51553	Diablo Systems .,Hayward,CA 94545
51642	Centre Eng .,State College,PA 16801
52648	Plessey .,Santa Ana,CA 92705
52676	SKF Inds .,Philadelphia,PA 19132
52763	Stettner Trush .,Cazenovia,NY 13035
53021	Sangamo Elctrc .,Springfield,IL 62705
53184	Xciton .,Latham,NY 12110
53421	Tyton .,Milwaukee,WI 53209
54294	Shallcross .,Selma,NC 27576
54297	Assoc Prec Prod .,Huntsville,AL 35805
54715	Shure Bros .,Evanston,IL 60202

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56289	Sprague .,North Adams,MA 01247
57771	Stimpson .,Bayport,NY 11705
58553	Superior Valve .,Washington,PA 15301
59730	Thomas & Betts .,Elizabeth,NJ 07207
59875	TRW .,Cleveland,OH 44117
60399	Torrington .,Torrington,CT 06790
61007	Townsend .,Braintree,MA 02184
61637	Union Carbide .,New York,NY 10017
61864	United Carr Fast .,Boston,MA
63060	Victoreen .,Cleveland,OH 44104
63743	Ward Leonard .,Mt.Vernon,NY 10550
65083	Westinghouse .,Bloomfield,NJ 07003
65092	Weston .,Newark,NJ 07114
70106	Acushnet Cap .,New Bedford,MA 02742
70109	Adams & Westlake .,Elkhart,IN 46514
70417	Chrysler .,Detroit,MI 48231
70485	Atlantic India Rubber .,Chicago,IL 60607
70563	Amperite .,Union City,NJ 07087
70611	Ark-Les Switch .,Watertown,MA 02172
70892	Bead Chain .,Bridgeport,CT 06605
70903	Belden .,Chicago,IL 60644
71126	Bronson .,Beacon Falls,CT 06403
71279	Cambridge Thermionic .,Cambridge,MA 02138
71294	Canfield .,Clifton Forge,VA 24422
71400	Bussmann .,St.Louis,MO 63107
71450	CTS .,Elkhart,IN 46514
71468	Cannon .,Los Angeles,CA 90031
71482	Clare .,Chicago,IL 60645
71590	Centralab .,Milwaukee,WI 53212
71666	Continental Carbon .,New York,NY
71707	Coto Coil .,Providence,RI 02905
71729	Crescent Box .,Philadelphia,PA 19134
71744	Chicago Min Lamp .,Chicago,IL 60640
71785	Cinch .,Chicago,IL 60624
71823	Darnell .,Downey,CA 90241
72136	Electromotive .,Willimantic,CT 06226
72228	Continental Screw .,New Bedford,MA 02742
72259	Nytronics .,Berkeley Hts,NJ 07922
72619	Dialight .,Brooklyn,NY 11237
72699	General Inst .,Newark,NJ 07104
72765	Drake .,Chicago,IL 60631
72794	Dzus Fastener .,W.Islip,NY 11795
72825	Eby .,Philadelphia,PA 19144
72962	Elastic Stop Nut .,Union,NJ 07083
72982	Erie .,Erie,PA 16512
73445	Amperex Elctrcs .,Hicksville,NY 11801
73559	Carling Elctrc .,Hartford,CT 06110
73690	Elco Resistor .,New York,NY
73803	TI .,Attleboro,MA 02703
73899	JFD Elctrcs .,Brooklyn,NY 11219
73957	Groov-Pin .,Ridgefield,NJ 07657
74193	Heinemann .,Trenton,NJ 08602
74199	Quam Nichols .,Chicago,IL 60637
74445	Holo-Krome .,Hartford,CT 06110
74545	Hubbell .,Stratford,CT 06497
74861	Industrial Cndnsr .,Chicago,IL 60618
74868	Amphenol .,Danbury,CT 06810
74970	Johnson .,Waseca,MN 56093
75042	IRC(TRW) .,Burlington,IA 52601
75376	Kurz-Kasch .,Dayton,OH 45401
75382	Kuka .,Mt Vernon,NY 10551
75491	Lafayette .,Syosset,NY 11791
75608	Linden .,Providence,RI 02905
75915	Littelfuse .,Des Plains,IL 60016
76005	Lord Mfg .,Erie,PA 16512
76149	Mallory Elctrc .,Detroit,MI 48204
76241	Maurey .,Chicago,IL 60616
76381	3 M Co .,St.Paul,MN 55101
76385	Minor Rubber .,Bloomfield,NJ 07003
76487	Millen .,Malden,MA 02148
76545	Mueller Elctr .,Cleveland,OH 44114
76684	National Tube .,Pittsburg,PA
76854	Oak Inds .,Crystal Lake,IL 60014
77132	Dot Fastener .,Waterbury,CT 06720
77147	Patton MacGuyer .,Providence,RI 02905
77166	Pass Seymour .,Syracuse,NY 13209
77263	Pierce Roberts Rubber .,Trenton,NJ 08638
77315	Platt Bros .,Waterbury,CT 06720
77339	Positive Lockwasher .,Newark,NJ
77342	AMF .,Princeton,IN 47570
77542	Ray-o-Vac .,Madison,WI 53703
77630	TRW .,Camden,NJ 08103
77638	General Inst .,Brooklyn,NY 11211
78189	Shakeproof .,Elgin,IL 60120
78277	Sigma Inst .,Braintree,MA 02184
78429	Airco Speer .,St Marys,PA 15867
78488	Stackpole .,St Marys,PA 15867
78553	Tinnerman .,Cleveland,OH
78711	Telephonics .,Huntington,NY 11743
79089	RCA .,Harrison,NJ 07029
79136	Waldes Kohinoor .,New York,NY 11101
79497	Western Rubber .,Goshen,IN 46526
79725	Wiremold .,Hartford,CT 06110
79727	Continental Wirt .,Philadelphia,PA 19101
79840	Mallory Controls .,Frankfort,IN 46041
79963	Zierick .,Mt Kisco,NY 10549
80009	Tektronix .,Beaverton,OR 97005
80030	Prestole Fastener .,Toledo,OH 43605
80048	Vickers .,St Louis,MO 63166
80103	Lambda .,Melville,NY 11746
80183	Sprague .,N.Adams,MA 01247
80211	Motorola .,Franklin Pk,IL 60131
80251	Formica .,Cincinnati,OH 45232
80258	Standard Oil .,Lafayette,IN 47902
80294	Bourns Labs .,Riverside,CA 92506
80368	Sylvania .,New York,NY 10017
80431	Air Filter .,Milwaukee,WI 53218
80583	Hammarlund .,New York,NY 10010
80740	Beckman Inst .,Fullerton,CA 92634
80756	TRW Ramsey .,St Louis,MO 63166

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80894	Pure Carbon .,St Marys,PA 15857
81030	Int'l Inst .,Orange,CT 06477
81073	Grayhill .,LaGrange,IL 60525
81143	Isolantite .,Stirling,NJ 07980
81312	Winchester .,Oakville,CT 06779
81349	Military Specifications
81350	Joint Army-Navy Specifications
81483	Int'l Rectifier .,El Segundo,CA 90245
81741	Chicago Lock .,Chicago,IL 60641
81831	Filtron .,Flushing,NY 11354
81840	Ledex .,Dayton,OH 45402
81860	Barry Wright .,Watertown,MA 02172
82219	Sylvania .,Emporium,PA 15834
82227	No.Amer.Philips .,Cheshire,CT 06410
82273	IN Pattern & Model .,LaPort,IN 46350
82389	Switchcraft .,Chicago,IL 60630
82567	Reeves Hoffman .,Carlisle,PA 17013
82647	Metals & Controls .,Attleboro,MA 02703
82807	Milwaukee Resistor .,Milwaukee,WI 53204
82877	Rotron .,Woodstock,NY 12498
82901	IN General Magnet .,Valparaiso,IN 46383
83003	Varo .,Garland,TX 75040
83014	Hartwell .,Placentia,CA 92670
83033	Meissner .,Mt Carmel,IL 62863
83058	Carr Fastener .,Cambridge,MA 02142
83186	Victory Eng .,Springfield,NJ 07081
83259	Parker Seal .,Culver City,CA 90231
83330	H.H.Smith .,Brooklyn,NY 11207
83361	Bearing Spclty .,San Francisco,CA
83587	Solar Elctrc .,Warren,PA 16365
83594	Burroughs .,Plainfield,NJ 07061
83740	Union Carbide .,New York,NY 10017
83766	Mass Engrg .,Quincy,MA 02171
83781	National Elctrcs .,Geneva,IL 60134
84411	TRW .,Ogallala,NB 69153
84835	Lehigh Metals .,Cambridge,MA 02140
84970	Sarkes Tarzian .,Bloomington,IN 47401
84971	TA Mfg .,Los Angeles,CA 90039
85604	Kepco .,Flushing,NY 11352
86420	Payson Casters .,Gurnee,IL 60031
86577	Prec Metal Prod .,Stoneham,MA 02180
86684	RCA .,Harrison,NJ 07029
86687	REC .,New Rochelle,NY 10801
86800	Cont Elctrcs .,Brooklyn,NY 11222
88140	Cutler Hammer .,Lincoln,IL 62656
88204	GTE Sylvania .,Ipswitch,MA 01938
88219	Gould Nat Battery .,Trenton,NJ 08607
88419	Cornell Dubilier .,Fuquay Varina,NC 27526
88627	K&G Mfr .,New York,NY
89265	Potter & Brumfield .,Princeton,IN 47671
89482	Holtzer Cabot .,Boston,MA 02119
89665	United Transformer .,Chicago,IL
89870	Berkshire Transformer .,Kent,CT 06757
90201	Mallory Cap .,Indianapolis,IN 46206
90303	Mallory Bat .,Tarrytown,NY 10591
90634	Gulton Inds .,Metuchen,NJ 08840
90750	Westinghouse .,Boston,MA 02118
90952	Hardware Prod .,Reading,PA 19602
91032	Continental Wire .,York,PA 17405
91146	Cannon .,Salem,MA 01970
91210	Gerber .,Mishawaka,IN 46544
91293	Johanson .,Boonton,NJ 07005
91417	Harris .,Melbourne,FL 32901
91506	Augat Bros .,Attleboro,MA 02703
91598	Chandler .,Wethersfield,CT 06109
91637	Dale Elctrcs .,Columbus,NE 68601
91662	Elco .,Willow Grove,PA 19090
91719	General Inst .,Dallas,TX 75220
91836	Kings Elctrcs .,Tuckahoe,NY 11223
91916	Mephisto Tool .,Hudson,NY 12534
91929	Honeywell .,Freeport,IL 61032
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92678	Edgerton Germeshuasen .,Boston,MA 02115
92702	IMC Magnetics .,Westbury,NY 11591
92739	Ampex .,Redwood City,CA 94063
92966	Hudson Lamp .,Kearny,NJ 07032
93332	Sylvania .,Woburn,MA 01801
93346	Amer Elctrcs Labs .,Lansdale,PA 19446
93618	R&C Mfg .,Ramsey,PA 16671
93916	Cramer .,New York,NY 10013
94144	Raytheon .,Quincy,MA 02169
94154	Wagner Elctrc .,Livingston,NJ 07039
94271	Weston .,Archibald,PA 18403
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95076	Garde .,Cumberland,RI 02864
95121	Quality Comp .,St Marys,PA 15857
95146	Alco Elctrcs .,Lawrence,MA 01843
95238	Continental Conn .,Woodside,NY 11377
95275	Vitramon .,Bridgeport,CT 06601
95348	Gordos .,Bloomfield,NJ 07003
95354	Methode .,Rolling Meadow,IL 60008
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96095	Aerovox Hi Q .,Olean,NY 14760
96341	Microwave Assoc .,Burlington,MA 01801
96906	Military Standards
97918	Linemaster Switch .,Woodstock,CT 06281
98291	Sealectro .,Mamaroneck,NY 10544
98474	Comper .,Burlingame,CA 94010
98821	North Hills .,Glen Cove,NY 11542
99017	Protective Closures .,Buffalo,NY 14207
99117	Metavac .,Flushing,NY 11358
99313	Varian .,Palo Alto,CA 94303
99378	Atlee .,Winchester,MA 01890
99800	Delevan .,E Aurora,NY 14052
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